CONSIDERATIONS FOR ESTABLISHING DSO CAPABILITIES IN ONTARIO

Final Report

Ontario Energy Board

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Glossary

Acronym	Term
ADMS	Advanced distribution management systems
ANM	Active Network Management
BCA	Benefits Cost Analysis
CP	Connections Provision
DERMs	Distributed Energy Resources management systems
DERs	Distributed Energy Resources
DFs	Design features
DMO	Distribution Market/Mechanism Operation
DNO	Distribution Network Operator (Actor)
DNO	Distribution Network Operations (function)
DNP&D	Distribution Network Planning & Development
DP-DSO	Dual Participation Distribution System Operator
DSO	Distribution System Operator
DST	Distribution System Test
EV	Electric vehicle
G&T	Generation and transmission
IAM	IESO-Administered Markets
IESO	Independent Electricity System Operation
TDWG	IESO's Transmission-Distribution Coordination Working Group
LDC	Local Distribution Company
LEM	Local Energy Market

Acronym	Term
MD	Market Development
MF	Market Facilitator
NWS	Non-wires solution
OEB	Ontario Energy Board
SSS	Standard Service Supplier
TDSO	Total Distribution System Operator
TSO	Transmission System Operator

DNV

1 Executive Summary

On behalf of the Ontario Energy Board (OEB), DNV investigated the potential introduction of Distribution System Operator (DSO) capabilities into the Ontario energy sector. DSOs[1] can play a critical role in grid management by steering electricity distribution through the network, including through the flexible deployment of Distributed Energy Resources (DERs) such as solar panels, wind turbines, and battery storage systems.

A number of Local Distribution Companies (LDCs) and entities in Ontario have studied DSO functionality to determine the possible benefits and costs of different DSO models. The current role of an LDC, also referred to as a distribution network operator (DNO), focuses on efficient ownership and operation of (the assets forming) its distribution network. DNV's initiative examines the scope, roles, requirements, and value proposition of implementing different DSO models in Ontario, enabling the OEB to evaluate and compare the viability and appeal of alternative DSO approaches for establishing DSO functionality. This includes the potential development of competitive marketplaces for buying (by DSOs and the IESO) and selling (by aggregators and operators of DERs) flexibility services.

This initiative considers a range of challenges and opportunities when designing and implementing a DSO model into an established energy sector. The following sections of the Executive Summary discuss what the initiative sought to understand for the Ontario energy sector, how we developed those considerations, and our main findings. Subsequent chapters describe the approach for each investigation in more detail as well as the outcomes.

1.1 Objectives

DNV and the OEB established the following objectives and associated research questions (Table 1-1) to guide our work.

[1] While there is no single definition, a DSO can be described as an entity with advanced capabilities to integrate, manage and optimize DERs for distribution and wholesale market services. DSOs actively manage distribution systems with high levels of DER penetration. They perform these functions with capabilities that can be considered incremental to those already undertaken by distributors. A DSO can serve multiple distributors, potentially having more opportunities to optimize DER flexibility.

Table 1-1. DSO functionality: objectives and research questions

Objective	Research questions	Project Task
1. Develop a common set of design features and considerations that define a DSO's structure, processes, and activities.	What features define different types of DSO implementation? What range of design features should we study to understand the trade-offs and implications when implementing a DSO in the Ontario landscape?	Design Features Framework
2. Understand the international DSO landscape through use cases for the creation, variation in structure, regulatory environment, maturity, themes, and outliers.	How are DSOs implemented internationally and what use cases led to their current structure? How have DSOs evolved since their original implementation? What are the best practices and implications of various design features?	Jurisdictional Review
3. Investigate and compare the implications of DSO implementation in Ontario using archetypical models.	Which features and considerations are appropriate for Ontario archetypical model development? How do the different DSO models impact services and products? How are roles allocated, and how are new roles introduced across different DSO models? What activities or functions need to be enhanced or created, across different DSO models?	Archetypical Model Development & Build-Out
4. Understand current use case of DSO value and market signposts/indicators for unlocking value in the Ontario context.	What are the common use cases behind DSO implementation, and how do they apply in the Ontario context? What system conditions signal these use cases, and what broad tipping points can be defined to indicate urgency of DSO implementation?	Archetypical Model Assessment
5. Understand the cost, benefits, risks, opportunities of each archetypical DSO model.	What are the relative costs when implementing different DSO models, and how do they compare to the potential benefits?	Archetypical Model Assessment

1.2 Study approach

To support our objectives, we designed a study approach to build and illustrate the considerations for designing and implementing a DSO model in Ontario. Figure 1-1 summarizes our approach and ties it to the research objectives above.

Figure 1-1. DNV's study approach

Objective	Task	Description
1	Design Features Framework	Features and considerations that, when combined, define a DSO's structure, processes and activities.
2	Jurisdictional Review	Understand global DSO models and their current implementation stages.
3	Archetypical Model Development	Develop DSO variations that could be tested and compared in later assessments.
3	Archetypical Model Build-Out	Characterize the four archetypical models according to roles, actors, functions, products, and services.
4	Archetypical Model Assessment	Identify the use cases and system indicators driving adoption of a DSO model in Ontario.
5	Archetypical Model Assessment	Compare costs and potential benefits across the 4 archetypical models as informed by the use cases

This study approach has several limitations that should be considered when interpreting the findings.

1. **DSO Model Selection for Analysis**: The four models chosen for this study are not exhaustive. They provide a reasonable range of analytical models to explore how various design features impact roles, activities, risks, costs, benefits, and subsequent regulatory considerations. However, the design methodology used in this study can be applied to assign different features or variations to the same models or to create new models that maximize benefits and minimize risks and costs, tailored to the Ontario context and evidence-based needs.
2. **DSO Use Case Assessment Sample Size and Evidence**: This analysis is based on four LDC interviews and relies on qualitative information obtained from those interviews to analyze the use cases for DSOs in Ontario.

3. **Cost-Benefit Analysis of the DSO Models**: The cost-benefit analysis in this study relied on qualitative evidence rather than quantitative evidence. Quantitative analysis would involve LDCs conducting a capabilities gap assessment and providing estimates of the systems, data, and skills needed to acquire certain DSO capabilities, alongside a quantitative assessment of system indicators that would support the use cases and value proposition for DSO. DNV discusses these use cases and value propositions in detail in Section 3.5.1.

1.3 Findings

DNV's findings enable the OEB to evaluate alternative approaches to establishing DSO functionality. The findings are informed primarily through comparison of the archetypical DSO models, identifying the relative costs, benefits, and associated risks.

Below, we present the key findings from our jurisdictional review, as well as the development, build-out, and assessment of the archetypical models. Due to length and format, we do not summarize the design features framework here but refer to Section 3.1for details.

1.3.1 Jurisdictional review

The jurisdictional research from Germany, the UK, the Netherlands, the US, and Norway/Sweden provided the foundational knowledge for the variation in DSO models, use cases, themes, and outliers. The insights from this research informed the development and assessment of the archetypical models as well as the "path forward" discussed at the end of the Executive Summary.

Table 1-2. Jurisdictional insights

Learning	Insight
Complexity of introducing DSO functionality	In any configuration, there is a high dependency/interaction between DNO and DSO, as well as with the TSO. Introducing DSO functionality on a system-wide basis is complex and costly and requires alignment across all relevant stakeholders.
Market-based solutions can provide long-term benefits	Market-based solutions stimulate innovation, can be technology-agnostic, and can reduce the overall costs of the energy system and energy transition, provided there is sufficient penetration and market participation of flexible resources, such as DERs.
Market development takes time, effort, and cost	Developing competitive and liquid flexibility markets requires significant investment, time, industry coordination, regulatory steering, and a high implementation effort to ensure that there is sufficient reliable flexibility to manage congestion and that the benefits of competition are fully leveraged. To deliver value-for-money for consumers, the development of flexibility markets must, therefore, be planned and timed carefully.

Learning	Insight
Customer confidence is critical	The market-based approach in Europe, while still in its infancy, has not been consistently effective, mainly because of low customer interest/participation. A regulated, rule-based approach may prove to be more effective in enhancing the reliability of, and derisking, DER flexibility – especially in the early development stage of flexibility use cases and flexibility supply.
DSO responsibilities can be changed over time	A limited set of DSO responsibilities may ease the effort to separate, or carve out, DSO from DNO functions, yet could still be an intermediate step towards the total-DSO model.
Functional separation builds confidence	A clear functional separation could mitigate or remove potential conflicts of interest and could, for instance, create more transparency in the choice between grid investments and non-wires solutions, building consumer/market confidence. Functional separation refers to the degree to which various DSO activities are separated from DNO functions.
DNOs are diverse	Small DNOs may be inefficient in, or incapable of, implementing DSO functions and/or undertaking necessary investments, or may have a lesser use for flexibility. This consideration could be an argument for a DSO-as-a-service model.
DSO models can evolve with market conditions	Coordination between IESO and DSO becomes increasingly important and complex as DER participation increases. Europe is not moving towards a total-DSO" model, yet potential conflicts between TSOs and DSOs have not yet been resolved in Europe, creating the potential for inefficiencies. A total-DSO model could be comparatively well equipped to avoid such inefficiencies.

1.3.2 Archetypical model development and build-out

DNV compared four models; three models were formulated as part of the archetypal model development, and the fourth was an interpretation of the IESO's Transmission-Distribution Coordination Working Group's MF-DSO model. Across these four models, we compared model structure, relative implementation costs, and costs relative to potential benefits. The archetypical models are not designed to be exhaustive and allow for further modification or refinement, as well as for the development of variants to test new concepts. These models were developed with a variety of design features to understand trade-offs and implications in the Ontario context.

Table 1-3 provides a high-level explanation of each model. All four models require creating new products in order for DERs to provide services to the DSO and the IESO.

Table 1-3. DSO models overview

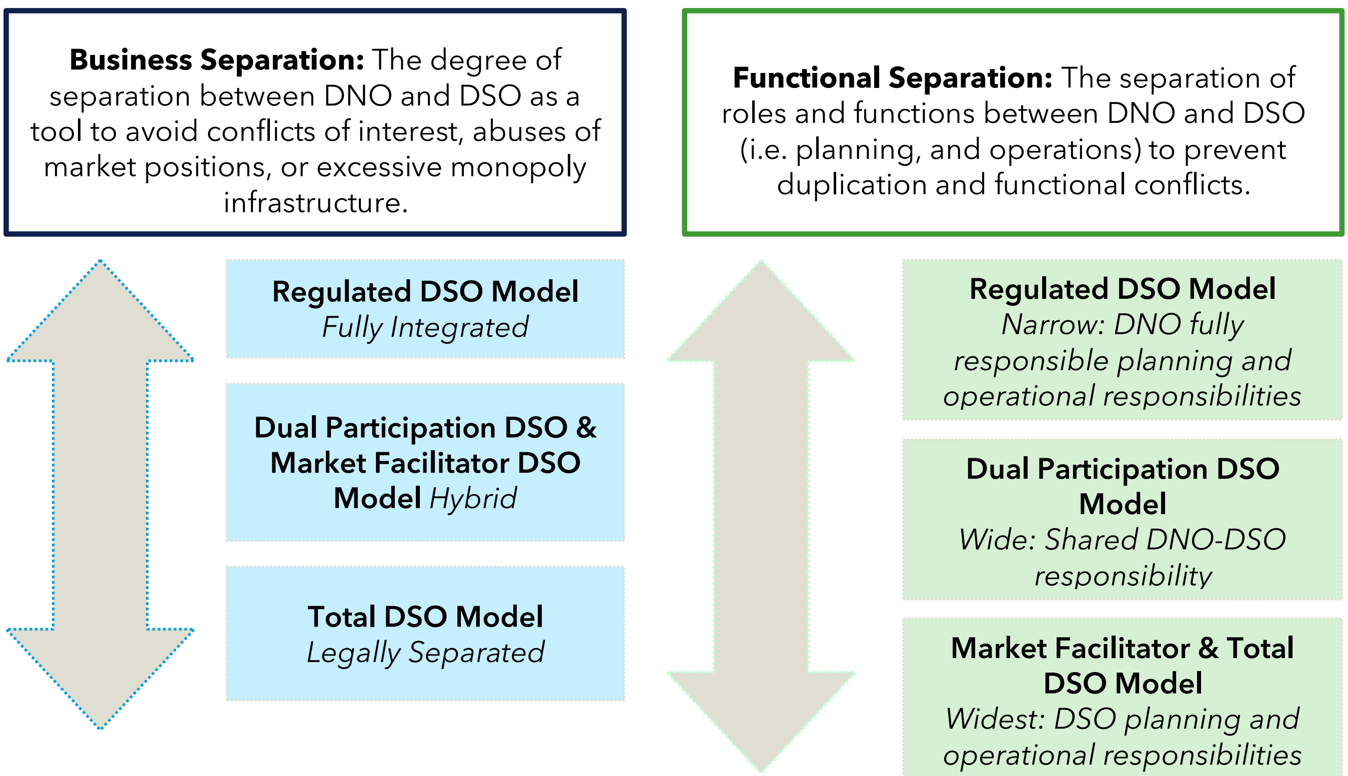
	Regulated DSO Model	Dual Participation DSO (DP-DSO) Model	Market Facilitator (MF-DSO) Model	Total DSO (TDSO) Model
Synopsis	This model is a continuation of the current status quo and can serve as a baseline model. This model supports the augmentation of DSO functions by applying rule-based mechanisms that may better fit the horizontal integration of DNO-DSO functions and in the absence of mature and reliable flexibility markets.	This model separates the DNO and DSO functions within the same organisation, allowing a market-based approach to DER integration yet limiting the DSO's network planning responsibilities.	This model separates the DNO and DSO functions within the same organisation, but without limiting the DSO's responsibilities in relation to network planning and with the DSO acting as a facilitator of flexibility at both Dx and Tx levels.	This model separates the DNO and DSO functions and businesses, allowing a market-based approach for DER integration, widening the DSO responsibilities compared to DP-DSO towards a total-DSO model.
Brief Overview of Roles	The DSO directly procures congestion management services through mandatory bilateral contracts, managing distribution network congestion, while the IESO handles transmission network congestion.	The DSO and IESO share responsibility for market administration. The DSO manages services to the distribution system and the IESO manages wholesale market services. DERs participate in wholesale markets directly or via aggregators.	The DSO acts as a non-commercial aggregator, optimises the distribution network, and coordinates with the IESO for wholesale market services.	The DSO operates distribution-level markets with DERs directly participating. For wholesale market services, the DSO acts as an aggregator, and DERs participate through the DSO.

DSO vs. DNO roles and responsibilities

With any of the four models described in Table 1-3, roles and responsibilities will need to be (re)defined and/or created. This is particularly true between the DSO and the distribution network operator (DNO). Currently, the role of the DNO is fulfilled by the Local Distribution Companies (LDCs) through the ownership and operation of (the assets forming) their distribution networks; LDCs also undertake certain DSO functions, for example with respect to the use of DER as NWS to meet distribution system needs.

The DSO transformation will require the articulation of distinct DNO and DSO roles and responsibilities, with varying degrees of business and functional separation described below in Figure 1-2.

Figure 1-2. DNO and DSO roles and responsibilities



To meet these responsibilities, new functions and activities will be necessary across all DSO models. Some activities will utilize existing capabilities, while others will require enhancements or entirely new capabilities.

Key risks

We have considered high-level regulatory, financial, and implementation risks across the four models. The following risks exist in all models, but their manifestation and consequences vary across the models considered.

Under all models, the **regulatory risk** to Ontario consumers lies in the continued need for regulated entities to recover efficient network costs, underpinned by either a well-defined regulated service or effective flexibility market arrangements.

The main **economic risk** is that DERs flexibility may not be economically efficient, for either DNOs or DERs, or both. This would lead to low(er) liquidity in flexibility markets, if the value is not there to pursue, it could undermine reliability of flexibility services. This also poses the potential for DSOs and other market actors to make inefficient investment or operational decisions.

The implementation of DSO functionality in Ontario inevitably requires the development of new skills, roles, functions, and responsibilities, accompanied by new rules, with new business/market/regulatory processes and new technologies. The overarching **implementation risk** lies in the complexity and breadth of these new activities. The incomplete or inconsistent implementation of any aspect of this spectrum can lead to inefficient actions or decisions by market participants.

1.3.3 Archetypical model assessment

Prior to assessing the performance of the models, we established the system conditions under which DSOs would bring value and address system needs. Table 1-4 below presents the use cases in Ontario developed through interviews with four LDCs.

Table 1-4. DSO use cases in Ontario

Use Case	System Condition
Non-wire solutions	Across networks in Ontario, system indicators suggest the need for identifying alternatives to traditional reinforcement, while currently manageable, is growing in importance and urgency. Because of the growing prevalence of DERs, this need could be met (at least in part) by using DERs to provide **non-wire solutions** (NWS) to reinforcement. A more detailed quantitative analysis of conditions on individual networks should be undertaken to validate whether NWS is viable on these networks.
Congestion	Although curtailment may not be a major problem in Ontario, there is a growing risk of **congestion** and other issues caused by both increased load on the network, including from DERs, and ageing assets, requiring repair and maintenance interventions. With a large part of the increasing load coming from DERs, there is the potential to provide congestion management services using the connected DERs.
Operational efficiency	DNV's qualitative scoring suggests that **operational efficiency** is the use case with the strongest current support within the Ontario context. Networks show signs of high levels of operational and financial inefficiencies, which DERs could help reduce. Operational efficiencies will

Use Case	System Condition
	ultimately make networks more economical to run and reduce costs for consumers.

Establishing the conditions above allowed DNV to assess and compare the potential implementation costs and benefits of a DSO under the above system conditions across the four models.

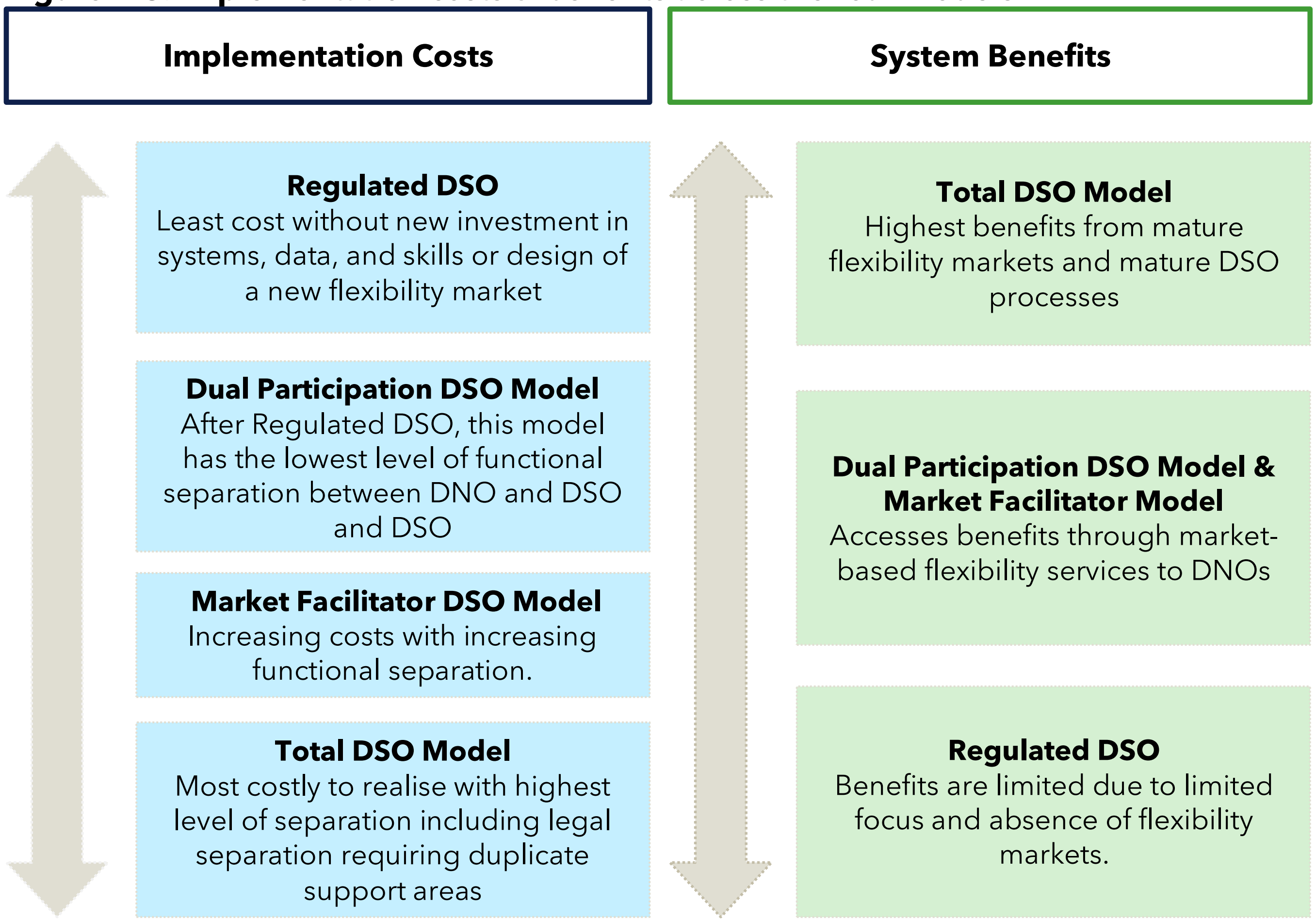
All parties including LDCs and DSOs, will incur costs during the DSO transformation. Key considerations relating to the cost effectiveness of each option include:

- Development of new systems, data, and skills
- Enablement and design of a new flexibility market
- Level of business and functional separation between DSO and DNO, i.e., number of new functions or duplicated support areas due to legal separation

Benefits are largely derived from the presence of flexible and mature DSO processes.

Figure 1-3 summarises the costs and benefits across the four models from the lowest to highest implementation costs and the highest to lowest potential benefits. On the cost side, the difference is driven by the degree of functional separation, and the avoidance of duplicate implementation costs where new functions are created. The main difference in potential benefits is driven by the level of a DSO's network planning responsibility and access to flexibility markets, which determines the potential for DSOs to maximise on commercial opportunities.

Figure 1-3. Implementation costs & benefits across the four models



1.4 Path forward

Timing is critical when developing a DSO. Investing too early would be inefficient for consumers in Ontario since they would fund investments ahead of need. Moving too late means foregoing the potential benefits of DER flexibility and the opportunity to tackle congestion-related issues at a cost to Ontario consumers. Because it takes years to develop DSO functionality and because market signals can and will change over the course of those years, the ideal path forward lays the groundwork for a DSO and prepares for nimble scaling and development as the landscape evolves. As such, our assessment does not identify the model with the absolute greatest value quantitatively but provides a qualitative comparison of the cost and benefit of a representative set of archetypical DSO models. This assessment can be used as a guide for navigating the complex timing of introducing a DSO model in Ontario given the strength of market signals and the tradeoffs between different models. The following reflections can inform the OEB as it continues its engagement with respect to DSO capabilities.

In the present, our analysis found qualitative evidence to support some DSO use cases (non-wire solutions, congestion and operational efficiency). Further (quantitative) evidence is desirable since the evidence was derived from LDC interviews, and this evidence shows DSO use cases and capability vary across the LDCs interviewed.

Looking to the future, the collective adoption of uniform DSO capability can maximise the benefits of DSO by maximising the routes to market for DER flexibility and building the supply side confidence that encourages investments in flexibility. This confidence can lead to a liquid, reliable, and economic market. Additionally, uniformity in coordinative processes and flexibility services ensures efficient deployment of flexibility, lowering the cost of market design, facilitation, and entry.

Preparing for that future is complicated. As the distribution system conditions change, so do the costs and benefits of a DSO. In this dynamic context, it is critical to monitor key system indicators: (1) the emergence of DSO use cases, (2) the (timely) development of DSO capabilities and functionality, and (3) the design and establishment of reliable, liquid markets (if warranted) for flexibility services.

While monitoring conditions, the OEB can use the insights from our model comparison to consider additional strategies. The Regulated DSO Model has comparatively low cost and might provide a safe test bed for a regulated flexibility mechanism, even if, over the long-term, the benefits it can deliver are limited. The DP-DSO, MF-DSO, and TDSO Models are more costly but could maximise potential once flexibility markets are in place.

Ontario does not need to select a preferred model at this stage. Even in the absence of a more quantitative assessment, developing the core functionality and capabilities to forecast, manage, and deploy DERs has little downside and these kinds of "low regret activities" could begin right away. Additionally, work can start on the design and standardization for DER flexibility products and services. As the urgency of market signals increases, the OEB should consider funding flexibility market capabilities.

Even amid an evolving market and a range of dynamic variables, the OEB can prepare for a DSO now without prematurely overcommitting or overinvesting. Setting long-term goals, remaining flexible in the pursuit of those goals, testing strategies within the existing framework, and investing in low regret activities that support several potential futures can all balance the duelling needs of DSO development: preparation and patience.

2 Introduction

2.1 Study & approach overview

On behalf of the OEB, DNV explored the scope, roles, requirements, and value proposition of integrating DSO functionality into Ontario's energy market.

Currently, LDCs focus on efficiently owning and operating their distribution networks. However, several LDCs and the IESO in Ontario are also assessing the potential benefits and risks of various DSO functions and frameworks. As introduced internationally, the DSO concept shifts the DNO from primarily an asset owner to an asset operator that actively manages the load on its network by deploying DERs such as generation, storage, and/or flexible demand response to meet distribution system needs. These capabilities change how LDCs interact with generators, customers, suppliers/aggregators, other LDCs, and the IESO, raising challenges and opportunities around the safety, reliability, and (economic) efficiency of the energy system.

Drawing on DSO best practices, this study aims to understand the opportunities, challenges, and regulatory considerations of implementing a DSO model in Ontario, delivering research, analysis, and expertise that explores:

- Distribution responsibilities and operations
- The potential structure and operation of a DSO model
- The dynamics between market participants

The study's findings will support the OEB as they consider and define policies that set expectations for DNOs as they develop DSO capabilities. The findings will also support policies that ensure DSOs are economically efficient for customers, LDCs, DER operators, and broader energy market participants.

While there is no single definition, a DSO can be described as an entity with advanced capabilities to integrate, manage, and optimize a high level of DERs for distribution and wholesale market services. Their capabilities can be incremental to those already undertaken by distributors. A DSO can serve multiple distributors, potentially generating more opportunities to optimize DER flexibility.

To better understand the DSO landscape, we conducted a range of investigations, analyses, and assessments to highlight the key factors in designing and implementing a DSO. These efforts included a jurisdictional review, a structural comparison, the development of use cases to identify common use cases for DSO development, and a comparative analysis of the costs associated with various DSO models.

The sections of this report detail the approach for each investigation and the resulting findings.

2.2 Report structure

Table 2-1 below presents the structure for the remainder of this study.

Table 2-1. Regulatory considerations for DSO – report structure

Section #	Title	Purpose
2	Introduction	Provides a more detailed introduction to the initiative and a guide to the report's structure
3	Approach & findings	Thoroughly details our approach to this initiative, with the major findings for each assessment in subsections 3.1-3.5
3.1	Design features framework	Reviews our approach to developing a design features framework and how/why this framework furthers the OEB's initiative
3.2	Jurisdictional review	Outlines the methodology and findings of our jurisdictional review, conducted to gain a deeper understanding of global DSO models and their current stages of implementation
3.3	Archetypical model development & selection	Details our approach and findings in creating archetypical DSO models
3.4	Archetypical model build-out	Outlines the methodology and findings—including a relative benefits assessment—from building out the archetypical models developed in the previous section
3.5	Archetypical model assessment	Assesses whether the Ontario electricity distribution sector will benefit from implementing the DSO models, along with the strengths and weaknesses of each model
4	Conclusion	Recaps our analysis and provides insights for the OEB to consider moving forward

3 Approach & findings

In this section, we detail our approach and findings for each of step of our assessment: Design features framework, Jurisdictional review, Archetypical model development, build-out, and selection.

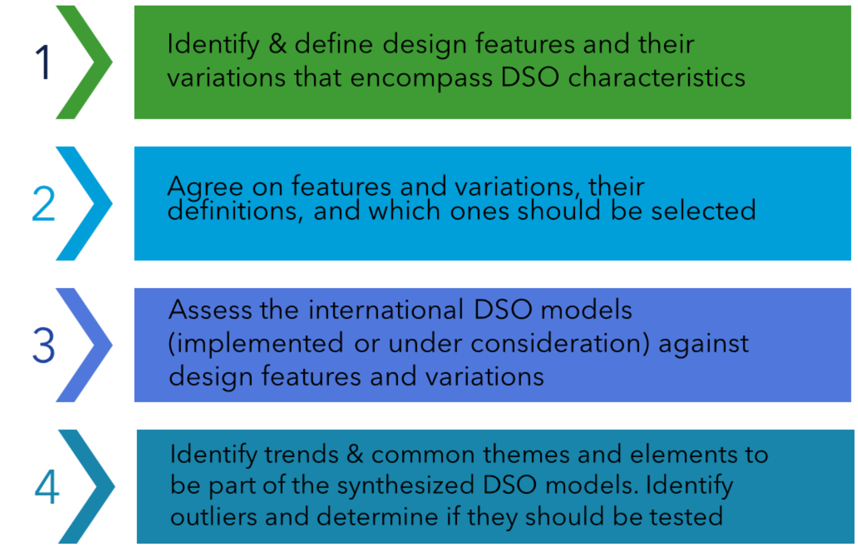
3.1 Design features framework

DNV used design features as a framework for exploring the DSO world. Design features are overarching themes that shape a DSO's structure, processes, and activities. The implementation or application of each design feature in a DSO varies, and we have also studied and defined those variants. This framework helped focus our efforts on the components most meaningful to Ontario and the OEB and allowed us to structure our jurisdictional research to support selection of an appropriate range of characteristics for the archetypical models.

3.1.1 Design features approach

Figure 3-1 below illustrates our approach to selecting DSO design features. Note that we completed a high-level jurisdictional scan to inform our design features framework, ensuring all variations were covered, while our in-depth review focused on those design features in the finalized framework.

Figure 3-1. DSO design feature selection methodology



We developed our approach to provide an understanding of the benefits, costs, and risks associated with implementing specific design features in Ontario.

DNV and OEB selected guiding design features that are fundamental to DSO model research and future selection of archetypical models. Table 3-1 summarises the guiding design features.

Table 3-1. Guiding design features and definitions

Feature #	Design feature	Definition
1	Business separation	The degree of separation between DNO and DSO, insulation against conflicts of interest, abuses of market positions, or excessive monopoly infrastructure
2	Functional separation	The degree to which various DSO activities are separated from DNO functions. Depending on the level of "business separation," functional separation aims to ensure market facilitation, prevent market distortions, safeguard against bias towards capital investment (e.g., DNOs may prefer traditional capital expenditure instead of exploring non-wire solutions), develop rigid DSO frameworks that align with regulatory best practices. These functions are relevant to market and commercial arrangements, the evaluation of flexibility solutions, network planning, operation, charging, etc. In this report, we use the terms narrow, wide, and widest to describe the spectrum of separation. Narrow separation means

Feature #	Design feature	Definition
		the DSO is only responsible for market and commercial arrangements related to securing flexibility. Wide separation means the DSO takes additional responsibilities beyond the narrow DSO. Widest separation means the DSO takes on significant responsibilities, including, for example, increased market operation and connections provision activities.
3	Hierarchy	The structure of the different layers in which a DSO can operate. When there is no vertical DNO – DSO integration, different structures can frame the status of DSO relative to the LDCs, the IESO, and other DSOs. For example, one option could be that there is one DSO in each of the current licenced LDC areas, while a different hierarchy exists for the DSO to operate across the same licenced areas as the IESO.
4	Ownership of flexible resources	Explores the ownership of flexible resources and their access to markets.
5	Flexibility mechanisms	Various mechanisms for accessing and securing flexibility, ranging from market-based mechanisms to bilateral (obligatory) services.
6	Flexibility market procurement and dispatch	Only applicable for those DSOs that include a market-based mechanism. The responsible party for procurement and dispatch of services for regional and provincial needs must be identified, and the market facilitator must be determined.
7	System coordination and operation	• The entity with operational responsibility for the local networks must be identified. • The entity with operational responsibility for the distribution system must be determined. • The coordination (or lack thereof) between DSO and the IESO control rooms must be clarified. • The party responsible for emergency restoration services from DERs must be specified.
8	Network design & development	• The DSO's role in long-term distribution network design and development must be defined. • The interaction between the DSO and the DNO must be described. • The leading entity must be identified.

Feature #	Design feature	Definition
		• The holder of the connection agreement must be specified.

3.1.1.1 Alignment of variants

In Table 3-2, the guiding design features are further characterized based on their variations or variants. The variations (or variants) reflect different implementation options for each design feature. Several variants are either considered or implemented by regulators or network businesses in leading European and North American jurisdictions.

During the framework development process, DNV examined variations of each design feature to ensure they covered all known and possible approaches in the market and all potential model structures. Some of these variations were updated based on Ontario activities.

To review definitions for each variant per design feature, please see APPENDIX A.

Table 3-2. Overview of design features and variants

Design Feature	Variants				
1. Business separation	1.1DNO-DSO horizontally integrated	1.2 Hybrid option – some activities are separated (ring-fencing)	1.3 Legal separation	1.4 Ownership separation or fully unbundled	
2. Functional separation	2.1 Narrow DSO Separation	2.2 Wider DSO Separation	2.3 Widest DSO Separation		
3. Hierarchy	3.1 One DNO to one DSO in a license area	3.2 nDNOs to one DSO across Ontario (where n represents an undefined number)	3.3 n DNOs to IESO (undertaking DSO activities)	3.4 DSO-DSO coordination across different voltage levels	
4. Ownership of flexible resources	4.1 DSO & market	4.2 DSO & non-market	4.3 3rd party		

Design Feature	Variants				
5. Flexibility mechanisms	5.1 Market-based within DSO's license area	5.2 Bilateral Agreements	5.3 DSO Active Management of Flexible Assets	5.4 Rule-based (Regulated Cost-Based mechanism)	5.5 Nodal market through wholesale mechanism
6. Flexibility market procurement and dispatch	6.1 DSO coordinates DERs and Local Flex Market	6.2. IESO coordinates DERs and Local Flex Market	6.3 Independent Market Facilitator (IMF)	6.4 IESO-DSO coordinate (dual participation)	
7. System coordination and operation	7.1 DSO lead	7.2 IESO-DSO joint coordination	7.3 IESO lead	7.4 IMF	7.5 No coordination
8. Network design & development	8.1 Long-term planning	8.2 Connecting existing/new customers	8.3 Outage planning		

3.1.2 Design features considerations

This subsection details various aspects considered by DNV and OEB during the development of the design features and variants. The considerations included the relevance to Ontario's energy sector and regulatory landscape of DSO design features observed in European jurisdictions.

LDCs structure: Ontario LDCs are highly heterogeneous compared to those in other jurisdictions (e.g., Great Britain). Any regulatory framework needs to allow for flexibility in how LDCs engage with a DSO. For example, some LDCs are in sparsely populated areas, with tens of thousands of customers. Others are almost entirely focused on urban areas, with hundreds of thousands to millions of customers. The density of the LDCs' customers can have an impact on the urgency to manage congestion and the scale of DSO implementation. In addition, at least a quarter of LDCs are embedded in another host distributor's territory.

The transition to DSO would most likely put pressure on smaller, embedded LDCs to acquire the necessary DSO capabilities, even though the need to transition is likely low. As such, we investigated a new concept, which we have not identified in other jurisdictions and warrants further consideration for Ontario: "DSO-as-a service." DSO-as-a-service involves larger entities providing services to smaller entities for which DSO investments might not be cost-effective. We tested this concept as a separate design variant under the design feature "hierarchy."

LDCs role: The integration of LDC business and distribution operations influenced the variants selected within the business and functional separation design features. For example, we examined the benefits of alternatives to the status quo where the DNO and DSO would be functionally separated.

DER ownership: LDC-owned DERs could create a conflict of interest if the DERs also participate in DSO flexibility markets alongside “independent” DERs (i.e., those not owned by DSOs, but, for instance, by commercial aggregators). LDCs could prioritise the DERs they own over others, and LDCs might leverage the value of their asset base to achieve preferential financial terms for investment and deployment of DERs. These concerns have been noted in European jurisdictions, and for this reason, European regulators only allow network-owner DERs by exception and for specific operational purposes.

Depending on the future regulatory framework, DER cost recovery mechanisms could prevent LDC-owned DERs from participation in DSO flexibility markets since the additional value earned in the market could be seen as double-dipping. We tested DER ownership by DSOs as a separate design variant but only in a concept where there is no flexibility market (Ownership of Flexible Resources).

Ontario precedents: The design features were informed by previous work undertaken by the IESO TDWG related to IESO/DSO coordination implementation options. For example, total DSO and dual participation models have been discussed by the IESO TDWG and stakeholders’ initiatives.

DNV shortlisted design features and their variants based on their ability to differentiate DSO models. The design features provide a flexible framework for selecting and comparing archetypical models and their structures.

3.2 Jurisdictional review

The transition towards DSOs is a critical development in the global energy sector, driven by the need to manage grid congestion, integrate renewable energy sources, and enhance grid reliability. DNV conducted a jurisdictional review to understand global DSO models and their current implementation stages.

3.2.1 Jurisdictional review approach

The jurisdictional review served two purposes:

- The review ensured that the design features and variants covered the range of models exhibited internationally.
- The research provided foundational knowledge of variation in DSO models, use cases, themes, and outliers.

The review highlights the unique approaches and regulatory frameworks adopted by Germany, the UK, the Netherlands, the US, and Norway/Sweden, showcasing the diverse strategies employed to address local grid challenges and promote efficient energy distribution. These jurisdictions were selected for review based on the following criteria:

- Level of DSO maturity (e.g. high level of maturity in the UK)
- Resemblance to Ontario (e.g., regulatory resemblance or similar use cases for DSO implementation)
- Unique implementation (e.g. Germany's regulated cost-based mechanism)

For each country and model, we detailed relevant policies and regulations; the presence of market characteristics; a high-level overview of the DSO model, including historical context, stakeholders, drivers, notable features, and status.

In addition to these country-specific overviews, we analysed the implementation of the design features and their variants in each country. This analysis was crucial in determining common trends in the design of global DSO models and identifying outliers and their causes. This analysis also provided a snapshot of design features across different DSO implementation models, enabling DNV to identify and test variants relevant to OEB's interests or applicable based on Ontario's current market and regulatory regime (e.g., legal separation, DSO-as-a-service, and flexible ownership).

Germany Overview & Drivers:

- To manage grid overloads, Germany relies on regulation-based management, including redispatch for renewable energy sources (RES) and combined heat and power plants.
- In Germany, the redispatch mechanism is mandated by regulation as a flexibility provision for system operators' congestion management. It is remunerated at a regulated price rather than market price.

Implementation Status:

- By regulation, generators with a capacity of 100 kW or more must adhere to Redispatch 2.0 and adjust their production when oversupply occurs. DSOs curtail plant output and compensate operators at a regulated price. Redispatch is voluntary for plants below 100kW generation capacity. Redispatch 2.0 applies to both transmission and distribution levels. Notably, Netze B.W. and EON, Germany's largest DSOs, are actively developing and implementing innovative tools and technologies. Unlike, the previous redispatch system, Redispatch 2.0 includes DERs, and DSOs are actively involved in congestion management.
- Redispatch 3.0, under development, may introduce market elements and allow demand to participate in the mechanism.

The Netherlands Overview & Drivers:

- Dutch DNOs face several challenges in their distribution networks, primarily grid congestion and capacity constraints, resulting in long connection wait times and the curtailment of new customers. These challenges have driven DNOs to undertake the DSO role with the associated DSO functions embedded within their DNO business. The main focus is on organizing a local flexibility market targeting local congestion, grid monitoring, and non-firm connection agreements.

Implementation Status:

- In principle, DSO markets are up and running, yet customer interest is extremely low on the demand-side, largely due to short term contracts with unclear financial incentives, a lack of standardization, and complex administration. Typically, capacity payments are involved, without any liquidity (today) in the Day-Ahead (DA_/Intraday (iD)) timeframe.
- To resolve congestion in the electricity grid, DSOs and TSOs have developed a joint procurement platform for flexibility called "GOPACS". Procurement needs are determined separately.

Norway/Sweden Overview & Drivers:

- DSO transformation in Sweden has been driven by congestion management and sharing capacity. In the Swedish electricity market, sharing capacity refers to the coordinated allocation of transmission capacity among different electricity market participants, primarily between TSOs and DSOs. The concept of sharing capacity is especially relevant for managing congestion, integrating renewables, and reducing long connection queues, challenges that are becoming increasingly problematic, particularly for the transmission network. DSO transformation in Norway is also supported by a regulatory framework that focuses on a stable energy mix and operational excellence. All DNOs are supposed to be DSOs.
- The overall regulatory approach combines minimal requirements for service level and quality with incentive-based remuneration, leaving it to the DNO/DSO to find the most efficient way to comply with customer needs and regulatory requirements.

Implementation Status:

- Most DNOs are DSOs in name only, though a few significant examples have emerged: Euroflex, a Norwegian pilot, and StockholmFlex, a permanent arrangement. Both share similar objectives, such as managing congestion.
- StockholmFlex is used by both DSOs and TSOs with the purpose of improving coordination between DSOs, as well as between TSOs and DSOs. Under their procurement hierarchy, DSOs use the platform to solve their own congestion issues, and the bids that haven't been selected by the DSO can enter TSO's mFRR market (i.e., frequency response balancing), if they are registered for TSO services provision.

UK Overview & Drivers:

- The push for net-zero and congestion challenges in the UK has been driving the UK regulator (Ofgem) to encourage DNOs to develop and use their networks more efficiently.
- This goal is integral to RIIO-ED2 (the current regulatory framework) incentives, which hold the DNOs accountable for delivering DSO functionality.
- Ofgem does not stipulate whether DSO should exist as a separate entity but stresses the need to avoid conflicts of interest.

Implementation Status:

The Energy Networks Association (ENA) Future Worlds[2] report was market-leading at the time of publication, analysing five different DSO transition paths for the UK. Although a specific path has not been adopted, this work spurred a number of initiatives for the UK industry under a "least regret" approach that adopts DSO elements that could fit any final DSO model. Hence, all DNOs have been acquiring DSO functions, with UKPN formally announcing their legal separation from the DNO business. All DSO markets are operational.

[2] https://www.energynetworks.org/assets/images/Resource%20library/ON18-WS3-14969_ENA_FutureWorlds_AW06_INT%20(PUBLISHED).pdf

United States (California; Massachusetts; New York)
Overview & Drivers:

- Many US utilities are being challenged to effectively serve new and changing grid needs, driven by high decarbonization goals, customer electrification, and adoption of DERs.
- In addition to changes to the distribution grid, business-as-usual (building more generation and transmission) does not look promising from an economic, reliability, or affordability perspective, pushing utilities to explore new regulations and policies that better align utility investments with state goals and customer needs.

Implementation Status:

- In 2023, the California PUC initiated the High-DER Future Grid Proceeding: Evaluating Alternative Distribution System Operator Models for California. To date, the Investor-Owned Utilities (IOU) and California ISO (CAISO) have expanded options for DER market participation.
- Massachusetts is exploring a UK-style flexibility market via the Grid Modernization Advisory Council initiative.
- New York State Energy Research & Development Authority (NYSERDA) has initiated a Grid of the Future plan which will explore DSOs as part of its 2030/40 vision.

3.2.2 Jurisdictional review findings

Our analysis highlights the diverse approaches and challenges DSOs face worldwide. To best organize our findings, we present our results in the following six categories:

Maturity: Most of the DSO transformation regimes are still young, though the UK and the Netherlands DSOs are more advanced, with robust flexibility markets, established roles and responsibilities, and/or regulatory frameworks that incentivise the DSO transition. The DSO transition is being driven by and paced by potential use cases and their level of urgency. Where congestion issues in the network are visible and urgent (e.g., NL, UK, Germany), the need to develop a flexibility mechanism and manage DERs is pressing. Where the need for use cases is less urgent and the focus is on future-proofing and operational excellence (e.g., Nordics), the DSO transformation is less mature.

Business separation: The majority of DNOs (LDCs) and DSOs are operating as a single legal entity. There are a few exceptions in the US and UK, where DSOs are exploring hybrid or legal separation models. Typically, a DNO and DSO are a single legal entity responsible for their licensed area.

Legal separation: More mature markets also consider legal separation, which requires a clear understanding of functional boundaries and the specific roles and activities of the DSO. Legal separation is primarily addressed in our business design feature and is related to the amount of functional separation. In the UK, a DSO handles functions such as long-term system planning and managing outages that impact DERs, while the LDC handles other types of outages. Legal separation is a potentially high-cost activity that is difficult to reverse, but it can be approached incrementally through a hybrid model that tests if full separation is necessary.

Market design: The most common feature among all currently implemented DSOs is a market-based approach which relies on open and competitive markets that adhere to the principle of neutral market facilitation.[3] Only Germany has applied a regulation-based approach because it could be applied more quickly and effectively. Germany faced significant challenges in grid management earlier than other European countries and, at the time, market-based congestion mechanisms were not able to manage the scale and complexity of grid challenges. However, Germany is considering market-based solutions as part of Redispatch 3.0.

Developing competitive and liquid flexibility markets is expensive and requires time, industry coordination, regulatory steering, and a high implementation effort to ensure that there is sufficient flexibility to manage congestion and that the benefits of competition are fully leveraged. Even the more mature markets (such as UK and Netherlands) and progressive regulatory frameworks (e.g., UK) have not yet achieved high liquidity of flexibility in DSO markets. The first UK DSO flexibility tender was procured in 2018. In 2024, the DSOs are still exploring how to improve their market design to confidently attract sufficient levels of flexibility.

Alternative flexibility mechanisms: Congestion management mechanisms such as the active network management[4] (ANM) of DERs by the DNO and bilateral agreements provide

[3] Neutral market facilitation refers to the fair, transparent, and unbiased operation of local electricity markets, where DSOs act as facilitators rather than competitors. It ensures that all market participants—such as distributed energy resource (DER) owners, flexibility service providers, and traditional network operators—can compete on equal terms without favoritism towards network-based solutions. Neutral market facilitation can be achieved via transparency in markets' operations, non-discriminatory procurement of flexibility services, fair and efficient market design, data transparency, coordination with IESO and other DSOs. The TDWG's MF model provides an implementation option of neutral market facilitation where the DSO acts as a neutral market facilitator by procuring services for its local area; forwarding services not used to the IESO; forwarding services to other DSOs in other regions; and coordinating with IESO on DERs that need to be dispatched through a shared market platform.

[4] Under ANM, customers connected to a DNO network agree with the licenced DNO to dynamic (non-firm) connection arrangements that allow their assets to be monitored and controlled by the DNO's ANM system. For example, when the grid faces constraints, customers with ANM connection may be curtailed or adjusted.

a good starting point for flexibility management and procurement prior to the development of fully operational flexibility markets. ANM and bilateral contracts can co-exist with market-based solutions. ANM solutions are common in the UK and are typically used as a queue and congestion management tool.

DSO-TSO Coordination: Procurement and dispatch of DERs require DSO-IESO coordination, with DSOs dispatching local flexibility and the IESO dispatching DERs for energy and transmission security services. The most common trend across the reviewed jurisdictions is DSO-TSO coordination,[5] though the "perfect" coordination model has not yet been implemented. Joint coordination requires clear rules to avoid conflicts of services.

DER ownership: In most jurisdictions, LDCs, and by extension DSOs, are prohibited from owning generation assets or flexible resources. In Norway, where LDCs are permitted to own DERs, they can only deploy DERs for operational purposes and are not allowed to deploy DERs in flexibility markets for commercial gain.

3.3 Archetypical model development & selection

In this section, we describe our approach to developing the four archetypical models, how we selected them, and our findings.

3.3.1 Archetypical model development & selection approach

Creating archetypical DSO models was a crucial step for determining which contrasts would be meaningful in Ontario and, therefore, which design features and variants should be assessed and tracked in the future. The selected models align with the following design priorities:

- Ontario-specific feasibility: Identify features and variants that are relevant to the Ontario market and previously considered by the IESO TDWG.
- OEB preference/priorities: Select features and variants that OEB would like to test.
- Industry best practice and trends: Align with clear and comprehensive trends that could be tested in one (or more) of the DSO models.

We defined a DSO model as a logical and feasible combination of the eight design features and underlying variants presented in Section 3.1, where the selection of some features determines the selection of others. For example, the variant selected for Business

Customers do not get compensated for being curtailed, instead they are offered a quicker and less expensive connection by the DNO. Since April 2024, new ANM customers in the UK will receive a compensation if their annual curtailment exceeds the curtailment limits which have been agreed in their contract. ANM customers can participate in DSO flexibility services, as ANM and DSO flexibility services can complement each other. DSOs typically define a hierarchy where ANM actions are taken first to manage local constraints. Flexibility services are then used as a secondary measure for broader or more complex issues.

[5] DSO-IESO coordination refers to the collaborative management of electricity grids between Distribution System Operators (DSOs) and Transmission System Operators (TSOs) to ensure grid stability, efficient energy flow, and seamless integration of decentralized energy resources (DERs). Key aspects of IESO-DSO coordination are the management of DER assets, flexibility services, grid congestion management, and coordinated market integration.

Separation would affect variants selected for the related design features Functional Separation and Hierarchy.

3.3.2 Archetypical model development & selection findings

Our selection approach resulted in three differentiated DSO models. We developed these models because they align with the design priorities described above and are sufficiently distinct to explore and demonstrate the impact of important regulatory choices.

We believe the three models represent a range that will allow the OEB to examine the key regulatory considerations for implementing DSOs in the province. The models, as currently defined by the eight design features and selected variants, also allow for OEB's exploration of wider aspects of DSO and DER deployment, including specific types of flexibility services, network tariff methodologies, and infrastructure requirements (i.e., those for smart meters and EV charging). It is conceivable that an alternative model will emerge to test new concepts, combining variants of the different models studied.

Table 3-3 below summarises the three models selected and DNV's design considerations.

Table 3-3. DNV's considerations for model selection

	Regulated DSO Model	Dual Participation (DP)-DSO Model	Total DSO Model
Main characteristics	Horizontally integrated, regulated mechanism	Functional separation, market-based mechanism	Fully separated
Synopsis	• Mainly a continuation of the current status quo and so can serve as a baseline model • Supports the augmentation of DSO functions by applying rule-based mechanisms that may better fit the horizontal integration of DNO-DSO functions	Separates the DNO and DSO functions, allowing a market-based approach to DER integration yet limiting the DSO's responsibilities	Separates both DNO and DSO functions and businesses, allowing a market-based approach for DER integration, widening the DSO responsibilities compared to DP-DSO and moving towards a "Total-DSO" model
Rationale for the synthesis	• In any configuration, there is a high dependency/ interaction between DNO and DSO. Carving out DSO	• Small DNOs may be inefficient or incapable of implementing DSO functions; this model	• As with the DP-DSO model, small DNOs may be inefficient or incapable of implementing DSO

	Regulated DSO Model	Dual Participation (DP)-DSO Model	Total DSO Model
	functionality may be complex and costly. • The market-based approach in Europe, albeit still in its infancy, has not been very effective so far mainly because of low customer interest/participation. A rule-based approach may prove to be more effective. • Balancing local markets and local energy communities against international and national markets is a challenge in European markets. An integrated model could ease the creation of local mechanisms, since responsibilities (including DER ownership) are less fragmented.	could allow for DSO-as-a-service. • A clear functional separation could mitigate or remove potential conflicts of interest and create more transparency when choosing between grid investments and non-wires solutions. • Market-based solutions stimulate innovation, can be technology-agnostic, and can reduce overall costs of the energy system and energy transition. • The choice for a limited set of responsibilities may ease the carve-out efforts, while taking an intermediate step towards the total DSO model.	functions; this model could allow for DSO-as-a-service. • Legal separation is a further step in removing potential conflicts of interest. • Coordination between IESO and DSO is increasingly important and complex as DER participation increases. Europe is not moving towards a total DSO model, and potential conflicts between IESO and DSOs have not yet been resolved in Europe, creating high inefficiencies. A total DSO model can potentially avoid these inefficiencies.

Table 3-4 further characterizes each model according to their selected design features and variants. Bolded content indicates where models—including a fourth model, the Market Facilitator Model in Table 3-5—share the same variant within the design feature to support model comparison.

Table 3-4. DSO models by design feature

Design Feature	Regulated DSO Model	DP-DSO Model	Total DSO Model
1. Business separation	1.1 DNO and DSO services are horizontally integrated	1.2 Hybrid model with DNO and DSO in the same organisation but with measures in place to reduce	1.3 DNO and DSO are separate legal businesses

Design Feature	Regulated DSO Model	DP-DSO Model	Total DSO Model
		the perceived conflict of interest	
2. Functional separation	N/A since feature 1.1 is in place	2.2 Wider separation of roles between DSO and DNO	**2.3 Widest separation of roles between the DNO and DSO**
3. Hierarchy	3.1 One DNO to one DSO	**3.2 Several (n) DNOs to one DSO (limited to certain narrow responsibilities)**	**3.2 Several (n) DNOs to one DSO (limited to certain narrow responsibilities)**
4. Ownership of flexible resources	4.2 DSO & 3rd-party ownership of flexible resources, but without DSO participation in the market	**4.3 Only 3rd-party ownership of flexible resources**	**4.3 Only 3rd-party ownership of flexible resources**
5. Flexibility mechanisms	5.3 Active Network Management 5.4 Rule-based mechanism (regulated cost-based)	**5.1-3 A combination of market-based mechanisms, bilateral agreements, and Active Network Management**	**5.1-3 A combination of market-based mechanisms, bilateral agreements, and Active Network Management**
6. Flexibility market procurement and dispatch	N/A since feature 5.4 is in place	6.4 IESO-DSO coordination with IESO is responsible for procuring DERs from 3rd parties to solve transmission congestion and balancing, while DSO is responsible for procuring DERs from 3rd parties to solve distribution congestion.	6.1.1 DSO takes greater responsibility and can provide services to transmission networks. DSO provides congestion services, playing the role of the aggregator (not the 3rd party)
7. System coordination and operation	**7.2.1 IESO-DSO coordinate (DSO coordinates with IESO in an emergency to restore the grid, e.g., black/brown out)**	**7.2.2 IESO-DSO coordinate (DERs can provide emergency and restoration services directly to the IESO through 3rd party Aggregators/FSPs).** Normal system operation is managed by the DSO for the distribution grid and by the IESO for the transmission grid.	**7.2.1 IESO-DSO coordinate (DSO provides emergency and restoration services from DERs to IESO, based on the IESO requirements)**

Design Feature	Regulated DSO Model	DP-DSO Model	Total DSO Model
8. Network design & development	• A separation between DNO & DSO of network design & development is not applicable for this model. • The Regulated DSO Model assumes DNO-DSO horizontal integration. The variants of this design feature depend on the position under Functional Separation. • When considering responsibilities within the same organisation but across teams, long-term planning and outage management remain mostly the responsibility of the "DNO" teams.	• This variation is strongly related to the degree of functional separation between the DSO and DNO. • In the narrowest DSO separation, the DNO would be responsible, yet would take the DSO capabilities (and costs) into account. For example, comparing grid reinforcements against non-wires solutions. • In the narrowest DSO separation, the DNO would be responsible for outage planning but would have to work closely with the DSO to ensure that planned outages do not impact the reliability of the network.	• This variation is strongly related to the degree of functional separation between the DSO and DNO. • In the widest DSO separation, the DSO would be fully responsible for the long-term planning of the network and would instruct the DNO to implement the results of this activity. • In the widest DSO separation, the DSO would be fully responsible for outage planning and would hand over the outage plans to the DNO for completion.

3.3.3 IESO TDWG's Market Facilitator (MF-DSO) Model

The IESO launched the TDWG to work closely with LDCs and other stakeholders to inform the DER Market Vision and Design Project, a key focus area of IESO's DER integration activities and the near-term DER Roadmap. The TDWG's overarching objective was to support the IESO in developing conceptual coordination protocol(s) that details communications among the IESO, LDCs, and DER participants for participation in the IESO-administered Markets.

The TDWG presented an assessment that identifies the operational and functional requirements, internal resourcing and capability development, and the associated costs incurred as LDCs transition into DSOs. This body of work is referred to as "B1 – Process & User Journey Map". The working group identified and compared three DSO models: total DSO, dual participation and Market Facilitator.

The MF-DSO Model provides another potential DSO structure. Table 3-5 maps the MF-DSO Model to the design feature framework. As with Table 3-4, bold text indicates overlap with another model.

Table 3-5. TDWG's Market Facilitator Model

Design Feature	MF-DSO Model
1. Business separation	**1.2 Hybrid model with DNO and DSO** in the same organisation, but with measures in place to reduce the perceived conflict of interest
2. Functional separation	**2.3 Widest separation of roles between the DNO and DSO**
3. Hierarchy	**3.2 Several (n) DNOs to one DSO (limited to certain narrow responsibilities)**
4. Ownership of flexible resources	**4.3 Only 3rd-party ownership of flexible resources**
5. Flexibility mechanisms	**5.1-3 A combination of market-based mechanisms, bilateral agreements, and Active Network Management**
6. Flexibility market procurement and dispatch	6.1.2 The DSO acts as a neutral market facilitator, procuring services for its local area, forwarding services[6] not used to the IESO, forwarding services to other (adjacent) DSOs in other regions (in case of a hierarchy), without going through the transmission network. In the latter scenario, other DSOs would not provide additional services to the wholesale market using forwarded, unused flexibility. Instead, they would utilize these DERs to meet their own local needs.
7. System coordination and operation	**7.2.3 IESO-DSO coordinate (DSO coordinates with IESO on DERs required to be dispatched for the energy market through a shared market platform.)**
8. Network design & development	This variation is strongly related to the degree of functional separation between the DSO and DNO (DF2). In the widest DSO separation, the DSO would be fully responsible for the long-term planning of the network and would instruct the DNO to implement the results of this activity. In the widest DSO separation, the DSO would be fully responsible for outage planning and would hand over the restoration plan to the DNO for completion.

3.4 Archetypical model build-out

This section outlines the methodology and findings of our archetypical model build-out process based on what we learned about the models in the previous section. It also includes an assessment of the relative implementation costs and benefits.

[6] Forwarding services means that the DSO is responsible for informing the IESO of bid prices and available quantities of services for each of the bidding service providers which are not used by the DSO. The DSO must pass this information to the IESO in a way that allows the IESO to dispatch and settle the service with the service provider.

3.4.1 Archetypical model build-out approach

Using the four models, we defined the roles, actors, functions, products, and services to highlight key differences and considerations. The approach is summarised in Figure 3-2.

Figure 3-2. Task process and activities

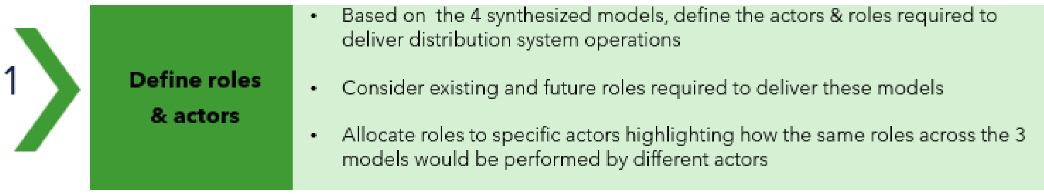
By defining the roles, responsibilities, and information flow, we provided a structured, visual, and intuitive way to understand complex interactions and relationships between various parties. The role definition also highlighted the possibility that a single actor may undertake multiple roles and the importance of separating roles where necessary to satisfy the information flows for a given process. This clarity can help avoid duplication of efforts, reduce misunderstandings, and establish accountability for actions and outcomes.

DNV also allocated DSO functions and activities to different actors, gave an overview of the underlying skills and capabilities required to deliver this functionality, and clarified the differences among the four DSO models.

Additionally, we identify regulatory, financial, and implementation risks to LDCs.

Each of the four tasks are defined in more detail in the following subsections.

3.4.2 Define roles & actors



We began our analysis by defining actors and roles to support the clear definition of and distinction between the models.

An **actor** is a party that participates in a business transaction. An actor may take on one or more roles and, as such, does not appear in the visualisation of the DSO models.

A **role** is the external intended behaviour of an actor. A role cannot be split among several actors.

The remainder of our analysis focuses on the following four actors:

- **IESO**
- **LDC** (including Standard Service Supply): Per the current definition, LDCs are utilities responsible for distributing electricity from high-voltage transmission systems to end consumers.
- **Flexibility Service Provider (FSP)**: A generalized term for DER or DER aggregator that provides services to the LDC or the IESO
- **DSO**: A new actor for the Ontario market, an entity responsible for operating the electricity distribution network within a specific geographic area. DSO could be considered both actor and role. The DSO "actor" can undertake different roles (and activities) within a DSO model. The "role" of DSO refers to the active operation of the distribution network. The full scope of roles for a DSO will vary depending on the model.

We then analysed which roles exist in each model and which of the current or new actors would perform this role in each model shown in Figure 3-3. Rows shaded blue have the same role designation across the four models. Definitions for each role can be found in APPENDIX B.

Figure 3-3. Summary of roles by model and actor

	Regulated DSO Model				Dual Participation DSO (DP-DSO) Model				Market Facilitator (MF) Model				Total DSO (TDSO) Model			
Role	**IESO**	**LDC**	**DSO**	**FSP**	**IESO**	**LDC**	**DSO**	**FSP**	**IESO**	**LDC**	**DSO**	**FSP**	**IESO**	**LDC**	**DSO**	**FSP**
Commercial Aggregator				x*				x				x			x	
Non-Commercial Aggregator			x				n/a				x				n/a	
Ancillary service provider	n/a							x				x			x	x
Capacity service provider	n/a							x				x			x	x
DER owner			x	x				x				x				x
Settlement Agent (IAM)					x				x				x			
Congestion management service provider				x				x				x				x
Dispatchable loads				x				x				x				x
Dispatchable generators				x				x				x				x
Distribution System Operator (DSO)			x				x				x				x	
Electricity System Operator	x				x				x				x			
Flexibility market/mechanism operator			x				x				x				x	
Non-dispatchable generator				x				x				x				x
Non-dispatchable loads				x				x				x				x
Real-time energy market operator	x				x				x				x			
Real-time energy market provider				x				x				x				x
Standard Service Supplier*		x				x				x				x		
Settlement Agent (Distribution)			X				X				x				x	
Distributor		x				x				x				x		

** We acknowledge there are also private suppliers available in Ontario. However, as they make up less than 10% of the market, our analysis will assume each LDC primarily acts as a Standard Service Supplier (SSS).*

We have introduced to the current Ontario structure new roles that will be required for the DSO functionality:

- To reflect the provision of different services to the IESO and the DSO, we have added the roles of the Ancillary Service Provider, Capacity Service Provider, and Congestion Management Service Provider.
- To reflect the entity that manages the flexibility markets or the regulated congestion management mechanism, we have added the role of Flexibility Market/ Mechanism Operator.

The key takeaways from allocating roles to different actors are:

- The scope of roles for a DSO increases with the level of functional separation; therefore, the Total DSO model implies the greatest number of roles for a DSO entity. The impact of functional separation becomes even more significant when examining the activities and responsibilities assigned to each role within each model (Section 3.4.4).
- Regulated DSO is the only model that does not have a flexibility market, rendering irrelevant various service provider roles.
- Regulated DSO is also the only model that allows a DSO to own DERs.

- LDC ownership of DERs for Non-Wires Solutions (NWS) is permitted in all models, with the assumption that these DERs do not participate in flexibility markets for commercial gain and the regulatory framework provides for the cost of DER ownership.
- The roles undertaken by IESO and LDCs remain the same across the three models. However, in the case of a horizontally integrated model (i.e., Regulated DSO Model), the LDC actor will be the same entity as the DSO. Hence, Regulated DSO Model will have one actor (i.e. LDC/DSO) who will undertake all the relevant roles.
- DP-DSO and MF-DSO Model have similar roles.

3.4.3 DSO functions

2 **Define functions**

- Compile a list with all the DSO functions and activities
- Highlight whether each function already exists, requires enhancements, or would be a new function
- Decide which functions and activities are performed by different actors based on each model
- Highlight the difference between wider and widest separation taking into consideration DP & Total DSO models functional separations and DSO-as-a-service concept

We grouped DSO functions into five categories, as shown in Figure 3-4. To describe how the functions would differ per DSO model, we analysed the various activities in each DSO function. For each activity, we determined whether it was an existing activity or would be new to DSO implementation. We also identified enhanced activities, which suggests additional tasks may need to be added to the existing activity as a result of DSO implementation. Please note that the status of the activity does not change across models; it is the applicability of each activity that differs.

The complete analysis can be found in APPENDIX C.

Figure 3-4. DSO functionality

Distribution Planning & Network Development (DP&ND)

DP&ND refers to preparing the distribution network for forecasted capacity requirements while securing the most efficient means of capacity provision to customers. The activities range from traditional investment planning, to co-ordination between the DSOs, the IESO and the Transmitters to identify whole electricity system options, including commercial DER options as well as distribution network investment and delivery of the new investment.

Distribution Network Operations

DNO refers to operation of the electricity distribution networks to maintain a safe and secure system. It covers a range of aspects, from ensuring the network power flows remain within thermal limits to minimise losses and managing future risks. Activities range from maintaining network visibility to supply of grid-operational services using DER assets.

Market Development (MD)	MD refers to the market arrangements put in place to provide flexibility services. Underlying activities of this function include assessing the value of flexibility, defining new services and supporting the operation of the markets and systems needed to provide these services. DSOs would also need to support the market participants through information provision.
Distribution Market/Mechanism Operation (DMO)	DMO refers to how network companies will operate local and regional areas through markets or regulated-based mechanisms and coordinate energy and power flow with other networks and systems to enable operation and optimisation across different timescales. The function focuses on day-to-day activities that are required to operate the different mechanisms to alleviate congestion.
Connections Provision (CP)	CP refers to the provision of distribution network connections and to managing ongoing access to the distribution network as well as activities that have emerged in the recent years, such as the management of increasing demand for connection to areas of distribution networks

The development of functions and activities for each DSO model resulted in the following takeaways:

Distribution Network Planning & Development and Connected Provision: This category has the most established activities and will likely require less effort to establish DSO functionality. For Distribution Planning and Network Development highlights planning and building the network as the main role of the DNO and as expected, most of the associated activities are well-established. New activities focus on planning for non-wire solutions (NWS) and coordinating with the IESO on whole electricity system solutions. New activities for Connected Provision functions are driven by the need to manage connection queues for DERs and the new responsibilities of the DSO, which owns DERs under the DSO-regulated model.

Market Development and Distribution Market/Mechanism Operation: As expected, the functions associated with the development and operation of the flexibility mechanisms or markets are mostly new to the IESO, the DSO, and the DNO.

Distribution Network Operations: This category includes some new activities, mainly driven by the use of ANM and the provision of grid-operational services using DER assets. It is worth noting that any activities related to the development and operation of a competitive flexibility market are excluded by the DSO-regulated model.

3.4.4 Activities & responsibilities

After defining DSO functions, we determined the core activities associated with each function. For example, within the Distribution Network Planning & Development function, long term forecasting for demand and generation including DERs is a core function. We allocated the activities and responsibilities to one of the following roles: LDC/DNO, LDC/DSO, IESO, DER Owner, other 3rd parties, and the DSO.

Full assessment of activities and roles is found in APPENDIX C.

Those allocations provided the following insights:

Distribution Network Planning & Development: Across all models, the LDC is responsible for network planning and outage management, investing in asset builds, and delivering new investment.

Across all models, the DSO is responsible for long-term forecasting, evaluating system solutions, and coordination with IESO and TSOs to support regional and whole system planning across all models.

In the Regulated DSO Model, the DNO is responsible for distribution system needs assessment and emergency response planning. For the other three models, the DSO takes on those responsibilities.

Distribution Network Operations: Across all models, the LDC is responsible for real-time network modelling, identification of constraints, outage restoration, network visibility, and real-time management.

Across all models, the DSO is responsible for the identification of congestion alleviation requirements and communication with DER owners.

In the Regulated DSO Model and DP-DSO, the LDCs are responsible for real-time coordination. In the MF-DSO and TDSO models, the DSO takes on that responsibility.

In the Regulated DSO and DP-DSO Models, the LDC/DNO is responsible for ANM management and operation. For the MF-DSO and TDSO Models, the DSO takes on those responsibilities.

In the Total DSO Model, the DSO provides grid-operational services using DER assets due to its comprehensive responsibilities. In the other models, DERs provide these services.

Market Development: The DSO performs most activities related to market development.

In the Regulated DSO model, there is no flexibility market to be developed, and most of the trade-related activities do not apply.

In the Regulated DSO and the DP-DSO Models, the DNO performs activities related to providing information to inform future investment. For example, the DNO should provide prospective DERs with information about the mandatory regulated congestion management mechanisms and ensure that DERs comply with the mandated requirements. In the MF-DSO and TDSO Models, the DSO takes on these activities.

Distribution Market/Mechanism Operation: This function has the most role differences across models.

In the Regulated DSO Model, the DSO has limited responsibilities as there is no market. However, the DSO is still responsible for deciding which assets to activate and control.

In the DP-DSO Model, the DSO has limited responsibilities regarding dispatching flexibility.

In the MF-DSO and TDSO models, the DSO undertakes all the activities concerning dispatching flexibility and performs the metering, billing, and settling of flexibility transactions.

In the MF-DSO Model, a shared platform (requirements to be determined by TDWG) enables coordination between transmission-distribution.

Connected Provision: The Regulated DSO and DP-DSO Models allocate Connected Provisions activities to roles similarly. The TDSO and MF-DSO Models differ in that the DSO is responsible for Connected Provision and management.

DER ownership by the DSO is only possible in the Regulated DSO Model.

3.4.5 DSO activities within functionally separated models

For three of the four models, the functional separation design feature calls for hybrid or legal separation between DNO and DSO. We evaluated the functions and activities that the DSO will assume under those functionally separated models.

- The DP-DSO Model assumes a hybrid model with a wider separation of roles between the DNO and DSO.
- The TDSO Model assumes legally separated roles performed by two different actors/legal entities, with the widest separation of roles between the DNO and DSO.
- The MF-DSO Model assumes a hybrid model with the widest separation of roles between the DNO and DSO.

The analysis doesn’t apply to Regulated DSO since it assumes that both roles are performed by the same actor/legal entity.

Table 3-6. below highlights the activities performed by the DSO in the DP-DSO and TDSO Models. The TDSO Model features the widest functional separation and, consequently, the greatest number of attributed activities.

Black text indicates activities carried out by the DSO in both the DP-DSO and TDSO Models. Blue text indicates those activities carried out by the DSO only in the TDSO Model but left to the DNO under the DP-DSO Model.

Table 3-6 and Table 3-7 detail the activities assumed by the DSO within the TDSO and MF-DSO Models.

Table 3-6. Additional DSO activities within the DP-DSO and TDSO Models

Distribution Planning & Network Development
Long-term forecasting demand and generation, including DERs
Identify capacity requirements on the distribution network, including analysis of DER hosting capacity / Assess distribution system needs, including flexibility requirements
Plan emergency response, including the update of planning criteria to account for the loss of DERs used for distribution services
Invest in distribution system solutions, including flexibility, asset builds, or smart solutions
Evaluate system solutions, including flexibility, asset builds, or smart solutions
Coordinate with the IESO and TSOs to identify whole electricity system solutions and support regional planning

Distribution Network Operation
Coordinate with embedded distributors, TSOs, IESO, and potential other DSOs on real-time operating constraints and the operation primacy on DER assets
Identify congestion alleviation requirements
Monitor ANM schemes
Operate ANM schemes
Communicate operating constraints to DER owners in real- or near to real-time (e.g., for outages or operation in alternate system configuration)
Supply of grid-operational services using DNO assets

Market Development
Define and (regularly) revisit services to be procured through distribution markets
Develop and, where possible, standardise terms & conditions for flexibility services
Develop and, where possible, standardise flexibility contractual processes
Develop and, where possible, standardise settlement processes
Develop and, where possible, standardise flexibility trading processes

Market Development
Develop distribution market rules including for non-discriminatory access to distribution markets and, where required by DER participation model, for facilitation of non-discriminatory access to IESO-Administered Markets (IAM) (e.g., develop flexibility services stacking rules)
Provide information to enable third parties to evaluate prospective investments for DER services
Market monitoring, compliance, and enforcement of distribution market rules

Distribution Market Operation
Develop updated cyber security requirements for DERs providing services to the distribution system
Translate network congestion into flexibility requirements
Impartially operate a local market for distribution services (excludes market for the transaction of energy)
Decide which assets should be activated
Operate and maintain distribution flexibility trading platforms
Manage and schedule DER activation, flexibility dispatch, and/or curtailment signals in accordance with operating agreements, contracted services, or based on market signals
Review activation of DERs to ensure such operation does not result in adverse distribution system impacts, including when a DER is activated in accordance with a bilateral contract or due to participation in IAM
For cases where DER is activated for distribution services, handle all metering, billing, and settlement
For cases where DER is aggregated by the DSO for participation in IAM, handle all metering, billing, and settlement
Assess and record flexibility providers' performance
Coordinate with the IESO (and other parties) the management and dispatch of flexibility

Connections Provision
Provide fair and cost-effective distribution network access
Provide a range of connection options that meet customer requirements and system needs efficiently
Provide data to potential DER applicants to inform DER development, including data related to system needs, forecasted curtailments, and historical curtailments

Study, approve, and set operating requirements for new DER connections
Facilitate queue management of DER connections

Table 3-7. Additional DSO activities within the Total DSO Model

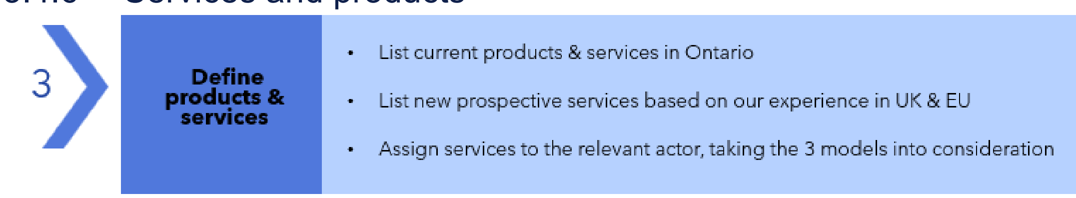
Distribution Market Operation
Depending on the DER participation model in IAM, aggregate DSO-activated DERs for participation in IAM (i.e., at floor prices for DSO-activated capacity)
Depending on the DER participation model in IAM, aggregate non-DSO-activated DERs for participation in IAM (i.e., as pass-through to IAM)

Distribution Network Operation
Supply grid-operational services using DER assets

Table 3-8. Additional DSO activities within the Market Facilitator Model

Distribution Market Operation
Operate and maintain distribution flexibility trading platforms (that is, shared activities between the DSO and IESO that are only present in this model)

3.4.6 Services and products



We analysed DSO services and products to document those currently operating in Ontario and so that we could apply our global expertise to identify potential new products and services. We also determined which actors would be responsible for delivering those potential new products and services, whether products and services would exist at the TSO or DSO level, and the type of procurement for each (e.g., auctions, real-time market, etc.).

Regulated DSO Model

Under the Regulated DSO Model, distribution network congestion management services are not procured through a marketplace. Instead, the DSO procures congestion management services directly with providers through mandatory bilateral contracts. These bilateral agreements provide congestion management for the distribution network, and the IESO manages the rule-based mechanism for providing congestion management to the transmission network. An example of this model in action is the ‘Redispatch 3.0’ trials (i.e., pilot projects) underway in Germany, where they are testing all flexible/controllable resources within the rule-based mechanism. Under this model, wholesale market participants are DER owners and aggregators – not the DSO.

Table 3-9. Regulated DSO Model service and products overview

Market / Mechanism		Procurer / coordinator	Service	Who provides service?	What is the service?
Tx-level services	Rule-based mechanism	IESO	Transmission congestion management	DERs above a certain size threshold (TBC), controlled by the IESO	Congestion management
	Wholesale markets	IESO	Transmission-level services such as network balancing, wholesale markets, etc.	The IESO will continue to procure services from transmission-connected market participants in-line with business-as-usual. There are trials to integrate DERs into IESO-administered markets,.	IESO-procured services cover a range of functions including network balancing, wholesale procurement, and the provision of operating reserves.
Dx-level services	Rule-based mechanism	DSO	Distribution congestion management	All DERs (of a size to be determined), controlled by the DSO, smart meter most likely to be required	Congestion management through a rule-based mechanism for generating technologies. In Germany, Redispatch 3.0 is under design and considering the inclusion of load-based technologies. A more "market-based" approach is being discussed.

DP-DSO Model

Under the DP-DSO Model, the IESO and DSOs would take dual responsibility for administering markets at the transmission and distribution levels. The DSO would take responsibility for service markets on the distribution network, and the IESO would take responsibility for service markets on the transmission network. Based on size thresholds determined by the wholesale market rules, DERs would be able to participate in wholesale markets, but aggregators, rather than the DSO, would coordinate this participation. DSOs would have no direct role in procuring wholesale market services but would be required to coordinate with the IESO to ensure that there are appropriate rules in place to minimise and mitigate conflicting DSO/IESO requests. Under this model, wholesale market participants are DER owners and aggregators – not the DSO.

Table 3-10. DP-DSO Model services and products overview

Market / mechanism		Procurer	Service	Who provides service?	What is the service?
Tx-level services	Wholesale markets	IESO	Transmission-level services such as network balancing, wholesale markets, etc.	All DERs through aggregators. There is no role for DSOs.	IESO-procured services cover a range of functions including network balancing, wholesale procurement, and the provision of operating reserves.
Dx-level services	Market-based DSO congestion management	DSO	Congestion management and grid restoration	All DERs in direct collaboration with the DSO	This would cover a wide-range of distribution-level services mainly focused on congestion management but also including grid restoration services.
	Flexible distribution network connections	DSO	Constraint management	DERs who connect to the grid with a flexible connection agreement	DERs can connect to the network with a "flexible connection agreement" that allows the network operator to restrict their connection if network constraints become too great.

MF-DSO Model

Under the MF-DSO Model, distribution-connected DERs can participate in wholesale markets. The DSO takes an approach that combines elements its approach under the DP-DSO and TDSO Models. The DSO plays the role of a non-commercial aggregator in the wholesale markets but gathers all bids for distribution and wholesale market services and optimises the distribution network before passing on remaining, eligible bids to participate in wholesale markets. The IESO will inform the DSO which bids to instruct, and the DSO will pass on dispatch information. The settlement of distribution-level markets will be managed by the DSO, while wholesale markets will be settled by the IESO. Under this model, wholesale market participants are DER owners and aggregators – not the DSO.

Table 3-11. MF-DSO Model services and products overview

Market / mechanism		Procurer	Service	Who provides service?	What is the service?
Tx-level services	Wholesale markets	IESO with a DSO coordinator and FSPs as aggregators	A range of wholesale market services such as congestion management, balancing, etc.	Transmission-connected assets and DERs through the DSO (acting as a coordinator of Dx / Tx services).	The services would cover all wholesale market requirements currently managed by the IESO including balancing, congestion management, and emergency restoration.
Dx-level services	Market-based DSO congestion management	DSO	Congestion management and grid restoration	All DERs in direct collaboration with the DSO.	This would cover a wide-range of distribution-level services mainly focused on congestion management but also including grid restoration services.
	Flexible distribution network connections	DSO	Constraint management	DERs who connect to the grid with a flexible connection agreement	DERs can connect to the network with a "flexible connection agreement" – allowing the network operator to restrict their connection if network constraints become too great.

TDSO Model

Under the TDSO model, DSOs would be responsible for operating markets at the distribution level, where DERs participate directly. At the wholesale market level, DERs would not directly participate in markets. Rather, the DSO would act as an aggregator and DERs would participate through the DSO. DERs are used to provide services at a wholesale market level, but the DSO is the wholesale market participant responsible for fulfilling any market related commitments. As a commercial aggregator under this model, the DSO is allowed to generate revenue by acting as an aggregator. For these wholesale market services, the IESO will still be responsible for procuring services, but the DSO will be the aggregator for DERs. Transmission-connected assets would continue to participate directly in wholesale markets.

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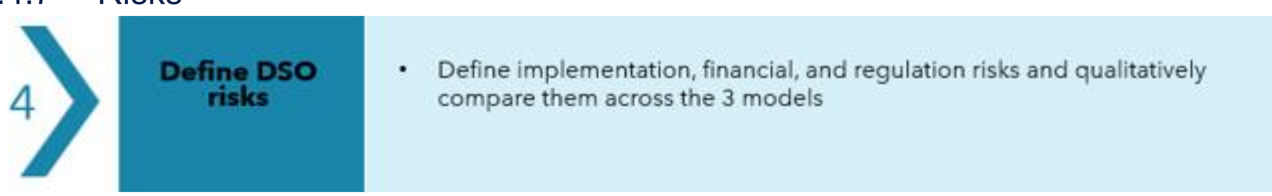
Table 3-12. TDSO Model services and products overview

Market / mechanism		Procurer	Service	Who provides service?	What is the service?
Tx-level services	Wholesale markets	IESO with a DSO aggregator	A range of wholesale market services such as congestion management, balancing, etc.	Transmission-connected assets and DERs through the DSO (acting as an aggregator)	The services would cover all wholesale market requirements currently managed by the IESO including balancing, congestion management, and emergency restoration.
Dx-level services	Market-based DSO congestion management	DSO	Congestion management and grid restoration	All DERs in direct collaboration with the DSO.	This would cover a wide-range of distribution-level services mainly focused on congestion management but also including grid restoration services.
	Flexible distribution network connections	DSO	Constraint management	DERs who connect to the grid with a flexible connection agreement	DERs can connect to the network with a "flexible connection agreement" – allowing the network operator to restrict their connection if network constraints become too great.

3.4.7 Risks



We considered the differences in the regulatory, financial, and implementation risks across the four models. This assessment is high-level and qualitative.

Regulatory risks

For all models, the regulated entity, be it the LDC or a joint LDC/DSO entity, assumes the risk of recovering only the efficiently incurred cost of operating the distribution network. The regulator must define a framework that does not reward LDCs for inefficient cost. For example, the cost of flexibility services incurred by the LDC cannot exceed the value of infrastructure deferral and does not expose the LDCs to commercial risk in emerging liquid flexibility markets.

Under the Regulated DSO Model, the regulator's definition of the regulated service and the pricing and deployment rules for that service pose a key risk for the LDC and the DSO. Those definitions and rules create operational risk and compromise the DSO's ability to recover the cost of operating the distribution network. In this model, extensive reporting and compliance requirements can increase administrative costs.

In the DP-DSO, MF-DSO, and TDSO Models, regulations focus on the performance of the DSO and govern the relationship between the DSO and LDCs, creating a level playing field among flexibility market participants. These models will require a well-structured regulatory framework to ensure that level playing field. The DSO's role as a neutral market facilitator should also be carefully defined to prevent conflicts of interest.

The main need is to develop the requisite rules and/or market arrangements (depending on DSO model), particularly those governing the relation between the DSO, LDCs, and alternative service providers. The regulator should also develop the framework for reporting and monitoring requirements.

Financial and economic risks

Across all models, the key risk is that the use of DER flexibility may not be economically efficient, either because of regulations and rules or competitive market prices, depending on the DSO mode. DER flexibility could become overpriced, meaning that traditional reinforcement would be more efficient, or underpriced, running the risk that the value proposition for DERs does not entice market entrants.

Customer confidence and willingness to participate is also a (possibly temporary) risk factor. Under the DP-DSO, MF-DSO, and TDSO Models, fledgling market participation could create a reliability risk if DSOs rely on DER flexibility that does not materialise. A possible longer-term risk is that overreliance on current or anticipated flexibility can delay investment in unavoidable network reinforcements. In these models, market-driven flexibility should not compromise service quality or increase costs to consumers. Again, the regulator must enforce consumer safeguards to ensure efficient pricing and service accountability.

In the Regulated DSO Model, well-defined incentives are required to ensure that DSOs do not overinvest in network infrastructure but pursue flexibility solutions where it is economically efficient.

Implementation risks

Across all models, there is a risk that key roles, functions, and responsibilities are not well defined or not completely or consistently implemented across the industry, particularly where new roles are created. The same applies to the development and implementation of market mechanisms, products, and services. If market participants make inefficient commercial decisions or do not coordinate efficiently, the market will not deliver efficient outcomes.

In all models, DSO implementation requires the workforce to develop expertise in flexibility, market operations, forecasting, and flexibility procurement (where applicable). In addition, all models require investment in advanced metering infrastructure, data management, and real-time monitoring.

All market-based models will require the development of flexibility products, market mechanisms, and new digital platforms. Arguably, the models that have increased responsibilities for the DSO and the widest functionality carry higher implementation risks, especially the TDSO and MF-DSO Models, where the DSO takes an active role in the coordination of services and the aggregation of DERs. In these models, transparent access to grid data and efficient provision of market information are crucial and require significant effort and resources.

3.4.8 Visuals of four models

The following visuals illustrate the interactions between the roles in each model.

Figure 3-5. Regulated DSO Model

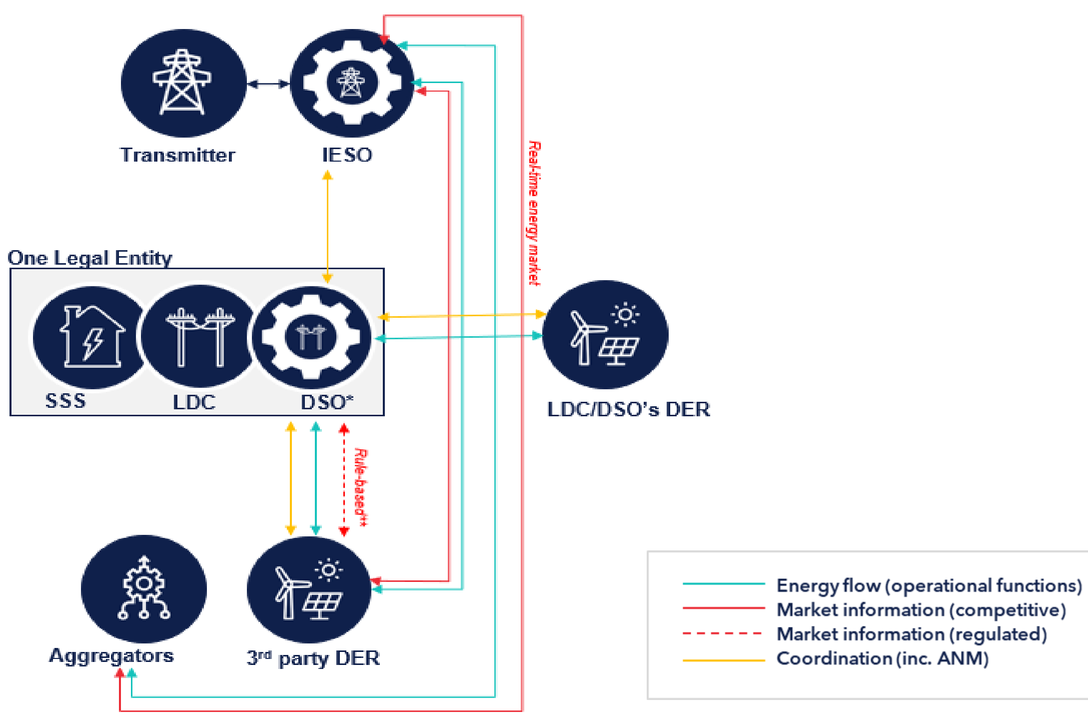


Figure 3-6. TD-DSO Model

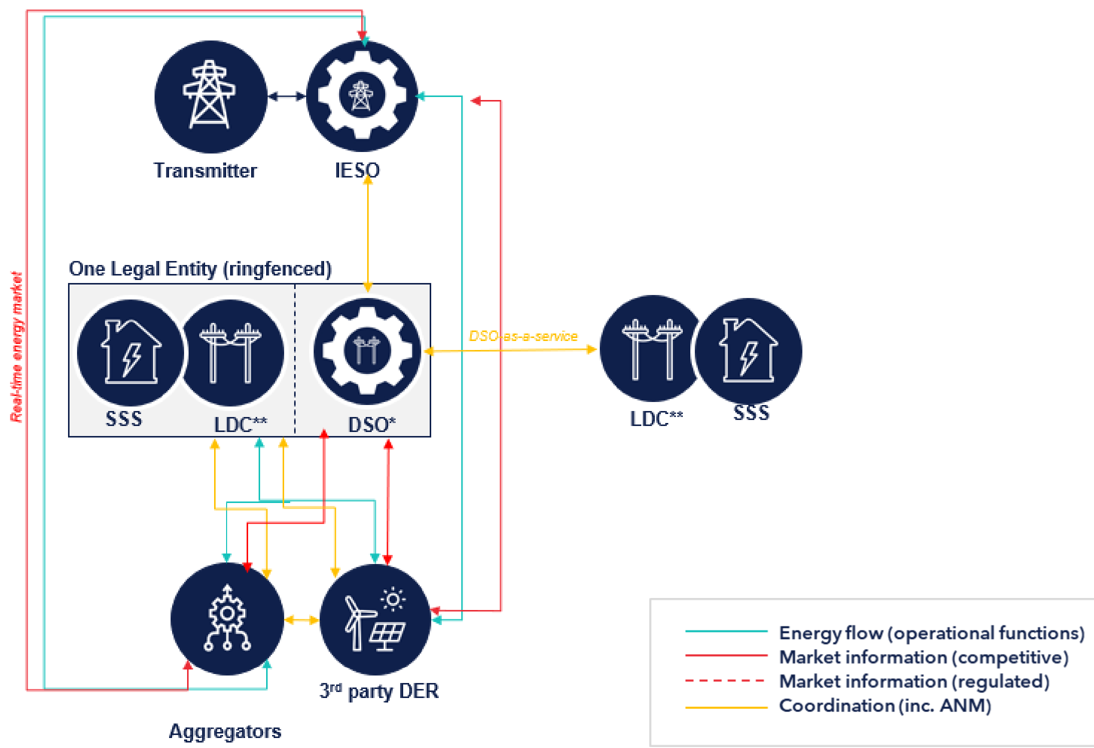


Figure 3-7. MF-DSO Model

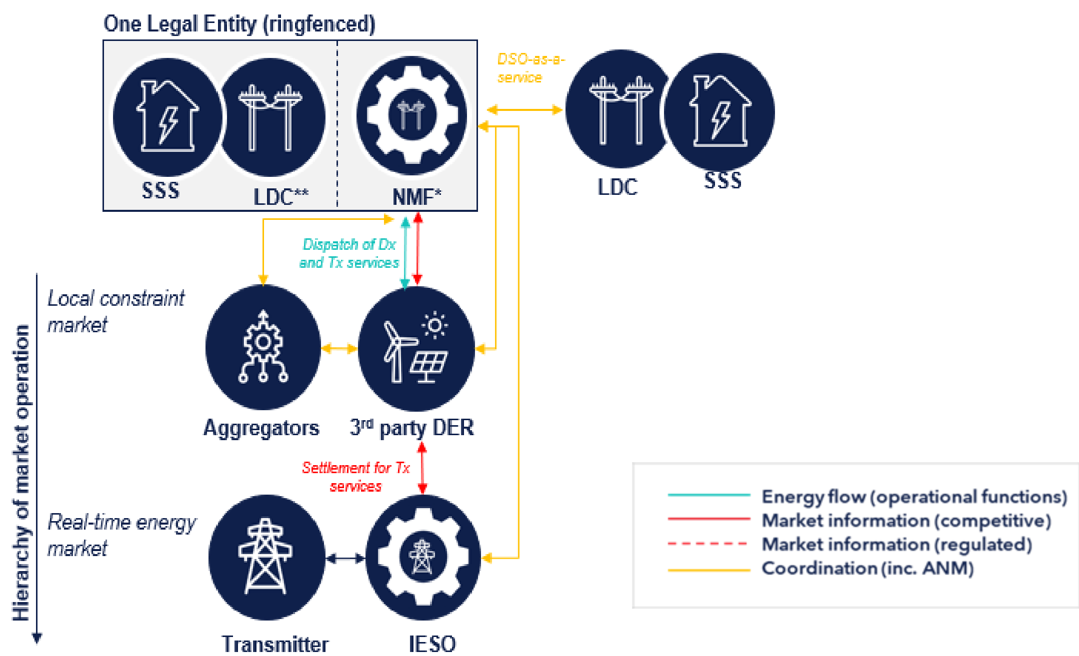
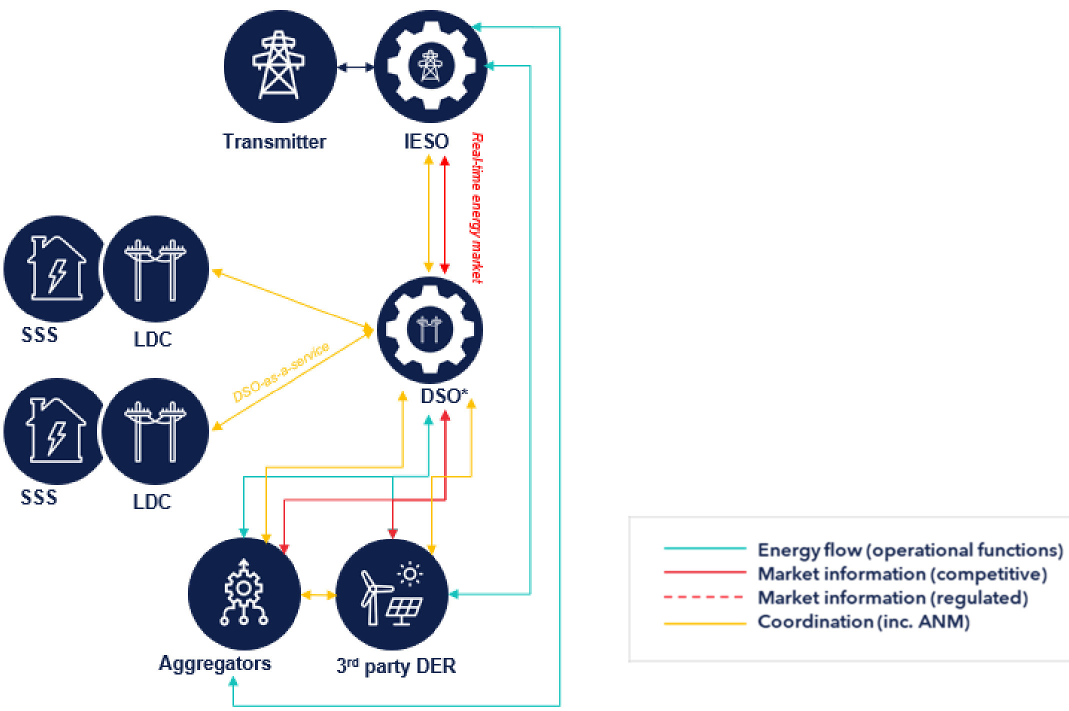


Figure 3-8. TDSO Model



3.5 Archetypical model assessment

Following the in-depth characterization of the four DSO models, we performed a series of assessments to understand whether the Ontario electricity distribution sector may benefit from the implementation of a DSO model and, if so, the relative strengths and weaknesses of each model. The assessment took the following steps:

1. High-level review of the international uses cases for DSOs and validation of use cases in Ontario via LDC interviews
2. Assess the relative benefits and costs of each model, using as a basis the roles, functions, and activities required for implementation
3. Qualitatively analyse the relative costs of the four selected DSO models
4. Qualitatively analyse the relative benefits of the four selected DSO models based on the benefits identified in the Distribution System Test (DST) and Energy System Test (EST) in the OEB benefit-cost analysis (BCA) framework

3.5.1 Potential use cases for DSO development

DNV used a digital survey instrument to interview four LDCs of varying sizes and characteristics to learn if, in their opinion, system conditions in Ontario support the introduction of a DSO. If the LDC thought a DSO might be suitable, the interview also explored common use cases that drive DSO creation. The list of use cases was developed during an industry review and incorporated into the digital survey and interview questions. No "hard data" was shared as part of these interviews and surveys, but LDCs did share their perspective and qualitative statements on the urgency of DSO implementation. Table 3-13 is a summary of the highlights from those interviews.

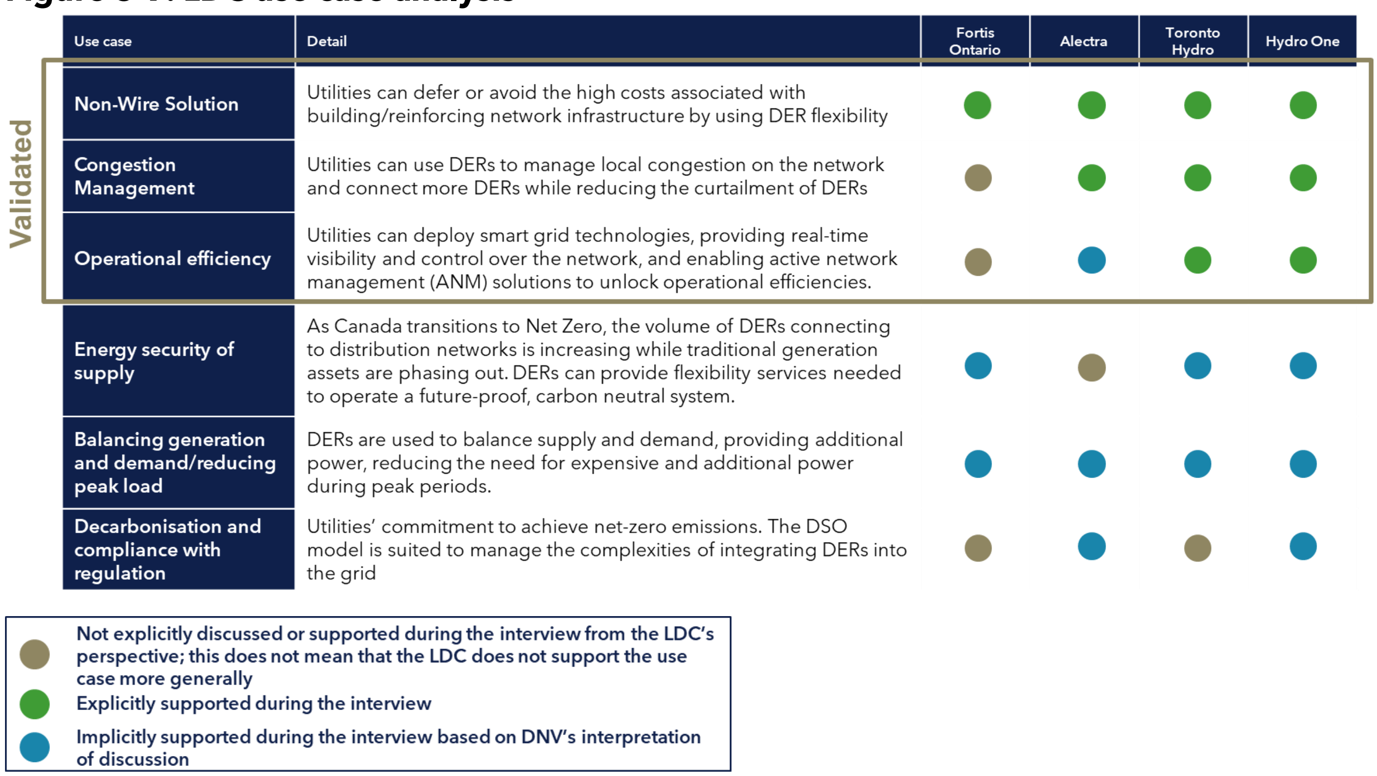
Table 3-13. LDC interview summary

LDC	Brief description	Brief summary of interview
FORTIS ONTARIO	A holding company for three small LDCs with a total of 69,000 customers. It serves mostly small communities in rural settings.	• Clearly articulated that DSO is not technically relevant to FortisOntario due to a lack of technical need. • Supported the theory of some of the use cases (mainly non-wires solutions for distribution and customer projects) but identified that they would not often be relevant to FortisOntario due to the size and system conditions on their networks. • If there was an investment / financial case to be made, they would consider it, but their system is unlikely to be the host of a DSO due to the size and availability of dispatchable DER.
alectra utilities	A municipally owned LDC formed by a combination of previously separate municipal LDCs. Mostly urban or suburban service areas with 1m+ customers.	• Two clear use cases are shown in Figure 3-9. • However, Alectra is not incentivised to pursue DSO as the regulatory framework does not reward OPEX investments in flexibility services. • Another major obstacle is network visibility and data quality issues across networks.
TORONTO HYDRO	A municipally owned utility that serves approximately 790,000 customers in Toronto.	• Three clear use cases are shown in Figure 3-9. • Has been able to procure flexibility through non-market agreements since 2015. • Agrees there is limited regulatory financial incentive for flexibility but notes that there are wider use cases such as operational improvements and reputation.
hydro one	Ontario's largest electricity utility, distributing electricity to 1.5	• Supportive of DSO and agrees with several use cases identified in Figure 3-9. • Already has flexibility products, but not yet managed through a market – e.g., thermostat

LDC	Brief description	Brief summary of interview
	million predominantly rural customers. A publicly traded company since 2015.	control of residential households (myEnergy Rewards program), which is used for local peak shaving or constraint management. • Biggest obstacle is the lack of proper remuneration to incentivize the procurement of flexibility. Strong advocates for a wholesale market facilitation model.

The interview results pointed to three uses cases that support the use of a DSO in Ontario: non-wires solutions, congestion management, and operational efficiency (Figure 3-9). While the interviews suggest that parts of the Ontario system would benefit from a DSO, additional research should identify specific networks and parts of networks that would gain the most value. This research should include a quantitative assessment of system indicators such as the length of interconnection queues, levels of curtailment, and network visibility.

Figure 3-9. LDC use case analysis



We developed a tool for each of the use cases to monitor system indicators. The suggested system indicators have been informed by DNV's experience helping develop DSO models in different jurisdictions (e.g., UK) as well as our familiarity with developments in other jurisdictions (e.g., Germany). Additionally, the indicators were informed by a review of existing literature on the system conditions that support the development of DSO models. The complete tool and analysis are found in APPENDIX D.

This tool serves as a guide for identifying key indicators rather than providing specific data or milestones from the Ontario energy system.

As an example, Table 3-14 illustrates the system indicators for the NWS use case. Based on the qualitative information from LDC interviews, DNV performed an aggregated, high-level scoring of system indicators across Ontario, assessing the viability and urgency of using DERs to provide NWSs in the Ontario electricity energy system.

- For each system indicator, the long-, mid-, and to short-term values indicate how urgently a transition to a DSO may be needed: the shorter the term, the more urgent the need.
- The following discussion details the assessment using **low**, **medium**, **medium-high**, and **high** values to describe the urgency of the system condition.

DNV recommends refining these ranges through further engagement with Ontario LDCs to develop a quantitative assessment, which would establish clearer tipping points for DSO implementation in Ontario.

Table 3-14. System indicators and urgency analysis for non-wire solutions

System Indicators	Description	Long-term	Mid-term	Short-term	Value
DER penetration	High DER penetration offers the ability for networks to explore NWS and may start to create complexities that require it	Low, dispersed <10% visibility	Variable across network, 10-30% visibility	High, concentrated, >30% visibility	**High**: on the LDC networks with the highest penetration rates, DER penetration (measured by % peak output generated by DER) is approaching 50%. However, it should be recognised that DER penetration is highly variable across networks and even within networks. DER provision is highest in utility-scale and industrial uses and lower at residential levels but is expected to grow at the residential level with electric vehicle adoption.
Hosting capacity	Where hosting capacity is limited, the ability to connect more DERS to the grid is limited. The greater the number of locations with reduced capacity across the network, the greater the urgency to intervene. NWS can help reduce peak loads.	High capacity (>40%), few locations facing limits	Medium capacity (20-40%), several locations facing limits	Low capacity (<20%), many locations facing limits	**Medium-high:** capacity is restricted in several locations and, traditionally, reinforcement would be expected. LDCs reported that the list of reinforcements required is growing.
Cost to reinforce*	The higher the cost to physically reinforce the network, the greater the benefit of avoiding such costs.	Low	Medium	High	**Medium**: not based on interviews as networks did not share costs due to regulatory sensitivities. DNV has assumed this need to be at least medium based on the global pressure on power network supply chains and inflationary pressures driving up costs

System Indicators	Description	Long-term	Mid-term	Short-term	Value
					(e.g. availability of raw materials and key plants such as transformers).
Time to reinforce**	Similarly, the longer reinforcements take, the stronger the case for NWS.	Fast, predictable	Medium	Slow, risky	**Medium-high:** firm timelines for reinforcement were not given. However, interviewees did state in some places that the list of reinforcements is getting longer and that the utilities are getting further behind. This fits with global trends where supply chain pressures and increased demand for connections are creating pressure on reinforcement timelines.
Connections queue***	Where queues are long, NWS can help to provide quicker (though limited) connections.	Short, queues decreasing in length	Medium, stable queues	Long, queues increasing in length	**Medium**: queues are generally understood to be manageable by LDCs. However, there is concern that the number of connection requests could increase, particularly if policies that support DER integration are introduced or expanded (e.g. IESO's Industrial Conservation Initiative which focuses on providing demand response).

**Cost to reinforce will vary greatly depending on the utility and the project.*

*** Supply chain, commodities prices, system access, skills & resources*

**** Connections queue lengths will vary from network to network. An important trend to understand is whether queue times are expected to increase, stay stable, or reduce.*

DNV summarizes this assessment's key findings:

Across networks in Ontario, system indicators suggest that the need to identify alternatives to traditional reinforcement is currently manageable but is growing in importance and urgency. Because of the growing prevalence of DERs, this need could be met (at least in part) by using DERs to provide **non-wire solutions** to reinforcement. A more detailed quantitative analysis of conditions on individual networks should be undertaken to validate whether NWS is viable on these networks.

Although curtailment may not be a major problem in Ontario, there is a growing risk of **congestion** and other issues caused by aging assets and increased load on the network. With a large part of the increasing load coming from DERs (e.g. electric vehicles, battery energy storage systems, electric heat pumps, etc.), there is the potential to provide congestion management services using those connected DERs.

DNV's qualitative scoring suggests that **operational efficiency** is the use case with the strongest current support within the Ontario context. Networks show signs of high levels of operational and financial inefficiencies, which DERs could help reduce. Operational efficiencies will ultimately make networks more economical to run and reduce costs for consumers.

For example, operational efficiency is a key use case for the move to a DSO in the UK. Ofgem's stated aim "is to drive licensees to more efficiently develop and use their network, taking into account flexible alternatives to network reinforcement."[7] DSOs can use smart grid technologies to obtain real-time visibility and control over the network and make more timely and cost-efficient operational decisions. Secondary network visibility, the cost-effectiveness of flexibility (compared to physical reinforcement), and the level of curtailment implemented on the network can all serve as metrics to determine whether distribution network and system operators are meeting goals.[8]

3.5.2 Cost and benefit assessment

DNV performed a relative assessment of the costs and benefits of each DSO model in three steps:

- Development of assumptions via roles, functions, and activities
- Assessment of costs
- Assessment of benefits

3.5.2.1 Assumptions

DNV used a staged process to determine which roles, functions, and activities would be required across the identified models, thereby inferring the underlying implementation

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[7] DSO Incentive Report 2023-24

[8] The Distribution System Operation Incentive Governance Document

costs. DNV used the previous work identifying roles and responsibilities from Sections 3.4.2, 3.4.3, and 3.4.5.

Table 3-15 maps the validated use cases (non-wires solutions, congestion management, and operational efficiency) to the associated DSO functions. This allowed for a high-level assessment of which functions are required to bring the fullest benefits across each of the models, as well as a high-level assessment of which models are simplest to implement.

Table 3-15. Use cases and relevant functions

Use case	Detail	Distribution Network Planning & Development	Distribution Network Operations	Market Development	Distribution Market/ Mechanism Operation	Connections Provision
Non-wire solutions	Utilities can defer or avoid the high costs associated with building new transmission and distribution lines by using DERs.					
Congestion management	Utilities can use DERs to manage local congestion on the network and connect more DERs while reducing DER curtailment.					
Operational efficiency	Smart grid technologies provide real-time visibility and control over the network. This helps to better manage the complexities of modern energy systems.					

Function required
Function only partially required for some models
Function not required (but benefits can be explored as PoC)

Market Development and Distribution Market/Mechanism Operation are scored **purple** for NWS and congestion management because the procurement of flexibility services through markets is a key tool for providing those use cases under two of the DSO models: DP-DSO and TDSO. However, market operation is not part of the Regulated DSO Model. Instead, flexibility would be provided through a regulatory mechanism.

Market Development and Distribution Market/Mechanism Operation are scored **brown** for operational efficiency because flexibility markets are not required to provide those services under any of the models. Operational efficiencies are primarily gained by leveraging automation, data analytics, real-time monitoring, and the integration of DERs to enhance efficiency and reliability.

3.5.2.2 Relative implementation costs

Our cost assessment is both qualitative and relative. First, DNV assigned a qualitative cost to the activities within each function, using a rating of low, medium, high, or highest based on the systems, data, and skills required to implement each activity relative to existing capabilities. Next, we aggregated the qualitative ratings across each function, indicating where each DSO model has a high concentration of costs compared to other models.

Table 3-16 presents the results of our assessment. For full details on assessment assumptions and costs by function see APPENDIX E.

Table 3-16. Aggregation of relative costs

Functions	Regulated DSO		DP-DSO		MF-DSO		TDSO	
	DNO Cost	DSO Cost	DNO Cost	DSO Cost	DNO Cost	DSO Cost	DNO Cost	DSO Cost
Distribution Network Planning & Development	Medium	Medium	Low	High	Low	High	Low	High
Distribution Network Operations	Medium	Medium	Low	High	Medium	Low	Low	Highest
Market/Mechanism Development	Low	Low	No Cost	High	Low	High	No Cost	High
Market /Mechanism Operation	Low	Medium	No Cost	High	Medium	Medium	No Cost	Highest
Connections Provision	Medium	Low	No Cost	Medium	Medium	No Cost	No Cost	Medium

No Cost	Existing capability therefore no additional costs incurred
Low	Relatively small improvements to existing capability
Medium	Relatively medium investment such as requiring transfer of systems/skills to new DSO entity
High	First implementation of a system; however, where the same system is needed to deliver other activities, the cost of the implementation is disregarded to avoid double accounting

Highest	Highest cost relative to other models

A detailed cost analysis of the models could reveal that specific functions and activities are significantly more expensive to implement for one model compared to the others. Such an analysis could suggest that a model with fewer high-cost scores might still be more expensive to implement than other models due to higher costs concentrated in specific areas.

Our key findings are:

- All parties, including DNOs and DSOs, will incur costs during the DSO transformation.
- The Regulated DSO Model is the most cost-effective option for implementing these functions. It does not require the systems, data, and skills necessary to enable a flexibility market. Additionally, the design work for the flexibility mechanism is less demanding compared to designing a market.
- The Total DSO Model is the most expensive option, driven by duplicated costs, particularly in business support areas such as HR, training, IT and telecoms, and board functions.
- Furthermore, the cost of MF-DSO and TDSO (widest separation) are higher than DP-DSO (wider separation) because costs increase with greater levels of separation between DSO and DNO functions.

3.5.2.3 Relative potential benefits assessment

DNV also took a qualitative and relative approach to the benefits assessment, referencing OEB's "Benefit-Cost Analysis (BCA) Framework for Addressing Electricity System Needs" for impact categories to consider. The qualitative assessment included both avoided costs and other benefits of each DSO model and focused on functions that address critical needs, improve efficiency, and contribute to cost savings. DNV did not consider Ontario-specific regulatory mechanisms, such as the FEI framework. APPENDIX E provides the full relative assessment. Since the assessment is qualitative rather than quantitative, DNV used the categories of highest, high, medium, and low benefit to develop a relative comparison across models.

Under similar circumstances, one DSO model may deliver higher or lower benefits relative to another model depending on:

- The structure of the DSO design features and functionalities
- The nature of the relationship between businesses and functions including the effectiveness of measures to separate businesses and functions
- The functions held by the underlying LDCs

Table 3-17 illustrates the aggregated benefits. While the aggregated assessment reflects the overall benefits, these aggregations do not fully explain why one model may be chosen over another. For that, a more comprehensive review that includes both quantitative and qualitative assessments of current systems and operational conditions would be required.

Table 3-17. Aggregated potential benefits

Benefits	Regulated DSO	DP-DSO	MF-DSO	TDSO
Avoided Energy Costs Benefit	Low	Medium	Medium	High
Avoided Generation Capacity Benefit	Low	Medium	Medium	High
Distribution Capacity (Deferral or Avoidance Benefit)	Low	Medium	Highest	High
Transmission Capacity (Deferral or Avoidance Benefit)	Low	High	Medium	Highest
Reliability (Net Avoided Interruption Costs)	Low	Medium	High	Highest
Resilience (Critical Load Benefits)	Low	Medium	High	Highest
Innovation & Market Transformation	Low	Medium	Medium	High
Planning Value	Low	Medium	High	High

3.5.2.4 Discussion of potential benefits

The following commentary compares the benefits and implementation costs of the four DSO models.

Table 3-18. Regulated DSO comparison

Benefits	Regulated DSO
Avoided Energy Costs Benefit	Low
Avoided Generation Capacity Benefit	Low
Distribution Capacity (Deferral or Avoidance Benefit)	Low
Transmission Capacity (Deferral or Avoidance Benefit)	Low
Reliability (Net Avoided Interruption Costs)	Low
Resilience (Critical Load Benefits)	Low
Innovation & Market Transformation	Low
Planning Value	Low

	Regulated DSO	
	DNO Cost	DSO Cost
Distribution Planning & Network Development	Medium	Medium
Distribution Network Operations	Medium	Medium
Market/Mechanism Development	Low	Low
Market /Mechanism Operation	Low	Medium
Connections Provision	Medium	Low

Regulated DSO is the least costly option, and its potential benefits are the lowest among the models due to its (1) limited scope (serving a single LDC), (2) minimal incentives to pursue cost savings and operational efficiencies, and (3) exclusive focus on a regulated congestion management service (including NWS but not ANM) without access to liquid, competitive flexibility markets.

TDSO Model has the highest potential benefits due to its minimal restrictions and strong incentives to pursue commercial returns, which maximise its ability to deliver value for LDCs. However, while it provides the greatest benefit potential, TDSO is also the costliest to implement and relies on mature flexibility markets and DSO processes to realize its full potential.

Table 3-19. TDSO Model comparison

Benefits	TDSO
Avoided Energy Costs Benefit	High
Avoided Generation Capacity Benefit	High
Distribution Capacity (Deferral or Avoidance Benefit)	High
Transmission Capacity (Deferral or Avoidance Benefit)	Highest
Reliability (Net Avoided Interruption Costs)	Highest
Resilience (Critical Load Benefits)	Highest
Innovation & Market Transformation	High
Planning Value	High

	TDSO	
	DNO Cost	DSO Cost
Distribution Planning & Network Development	Low	High
Distribution Network Operations	Low	Highest
Market/Mechanism Development	No Cost	High
Market /Mechanism Operation	No Cost	Highest
Connections Provision	No Cost	Medium

DP-DSO Model and **TDSO Model** have a greater potential to deliver benefits because of the possibility of serving multiple LDCs and providing multiple market-based flexibility services, assuming flexibility markets emerge and mature.

Table 3-20. DP-DSO Model comparison

Benefits	DP-DSO
Avoided Energy Costs Benefit	Medium
Avoided Generation Capacity Benefit	Medium
Distribution Capacity (Deferral or Avoidance Benefit)	Medium
Transmission Capacity (Deferral or Avoidance Benefit)	High
Reliability (Net Avoided Interruption Costs)	Medium
Resilience (Critical Load Benefits)	Medium
Innovation & Market Transformation	Medium
Planning Value	Medium

	DP-DSO	
	DNO Cost	DSO Cost
Distribution Planning & Network Development	Low	High
Distribution Network Operations	Low	High
Market/Mechanism Development	No Cost	High
Market /Mechanism Operation	No Cost	High
Connections Provision	No Cost	Medium

DP-DSO Model has a high benefit potential but is less strongly incentivized to max benefits at system level because of its ties to LDC. The model does benefit from these ties through greater knowledge, a boon to reliability, resilience, and planning services.

DP-DSO Model also offers a balance between the cost of implementation, which would be lower than TDSO, and the potential benefits offered by the provision of market-based flexibility services to multiple LDCs.

The cost to implement **MF-DSO Model** are high compared to the other models due to the need for duplication of functions at both the DNO and DSO. Although not as high as TDSO, MF-DSO has a higher benefit potential than DP-DSO. Its control of DERs allows it to

Table 3-21. MF Model Comparison

Benefits	MF
Avoided Energy Costs Benefit	Medium
Avoided Generation Capacity Benefit	Medium
Distribution Capacity (Deferral or Avoidance Benefit)	Highest
Transmission Capacity (Deferral or Avoidance Benefit)	Medium
Reliability (Net Avoided Interruption Costs)	High
Resilience (Critical Load Benefits)	High
Innovation & Market Transformation	Medium
Planning Value	High

	MF	
	DNO Cost	DSO Cost
Distribution Planning & Network Development	Low	High
Distribution Network Operations	Medium	Low
Market/Mechanism Development	Low	High
Market /Mechanism Operation	Medium	Medium
Connections Provision	Medium	No Cost

optimise outcomes for its local DNO and to leverage its role in network and outage planning.

From this relative benefits assessment, we derived the following insights:

TDSO Model has both higher costs and potential benefits due to the complete separation of DNO and DSO. The key to TDSO's potential benefits is the greater market access for DSOs under this model compared to the DP-DSO Model. TDSO's inclusion of an aggregator to provide DNO and IESO services, further supported by DSO responsibility for DNO long-term network and outage planning. These properties enable DSOs to optimise DER portfolio deployment and to capitalise on flexibility market opportunities.

DP-DSO Model will cost less to implement than the **TDSO Model** since DP-DSO builds off existing infrastructure, creating DSO functions within the same organisation. Some cost and effort are required to ringfence the functions and manage real or perceived conflicts of interest in the procurement and deployment of DERs in a competitive market.[9] Ringfencing costs in DP-DSO would be lower than the cost under TDSO, which as designed for this initiative requires a complete legal separation of businesses and functions.

Compared to TDSO, DP-DSO has fewer potential benefits, as it is not responsible for long-term network or outage planning. Instead, it relies on outcomes driven by the DNO, which may prevent it from fully coordinating DNO needs with the flexibility capabilities of the DERs under its control. The DSO in DP-DSO does not act as an aggregator for DERs and, therefore, is unable to optimise the deployment of DERs on an individual or portfolio basis.

MF-DSO Model has design elements of both DP-DSO and TDSO. MF-DSO builds on the existing infrastructure of the LDC to create DSO functions within the same organization but institutes the widest functional separation, incurring significant ringfencing costs, though not quite at the level of TDSO. Compared to DP-DSO, the DSO in MF-DSO plays a greater role in collecting the bids and prioritising the local network, which potentially increases its ability to maintain and address reliability issues, increase the resilience of the distribution system, and support system coordination and planning.

In **Regulated DSO Model**, the DNOs take on the DSO function and require the least amount of change to the existing structure and system. We did not assess Regulated DSO as having any high costs, other than ownership of DERs, which may already be incurred by the DNO. Regulated DSO is considered the least risky since there are no significant changes to planning, operations, or regulatory processes – except for the need to create a regulated

[9] With the DSO and the DNO being in the same organisation, isolating the DSO staff, functions, and systems from the DNO business reduces the incentives and the potential for the DSO to bias procurement or operational decisions for the benefit of the DNO. For instance, the DSO could prioritise deployment of DERs for the DNO, even if there is a higher system value (and willingness to pay) to serve IESO or another DNO. Such behaviour, or perceptions of such behaviour, would undermine confidence in flexibility markets and the reliability of the service. The cost of ringfencing are those costs required to realise and maintain separate assets or activities, as well as the costs of investing in new/duplicate systems for the DSO.

flexibility product and mechanism. LDCs will continue to lead distribution planning and operations but with increased capabilities.

However, **Regulated DSO Model** has the least potential to unlock the benefits, since the DSO only serves one DNO, with a single service, and there is no opportunity to stack value from other services or in other markets or to optimise the deployment of DER resources on a portfolio basis. The absence of markets also means that the DSO would not face the “competitive pressure” from a market environment that can ensure cost (pricing) efficiency.

4 Conclusion

Timing is critical when developing a DSO. Investing too early would be inefficient for consumers in Ontario since they would fund investments ahead of need. Moving too late means foregoing the potential benefits of DER flexibility and the opportunity to tackle congestion-related issues at a cost to Ontario consumers. Because it takes years to develop DSO functionality and because market signals can and will change over the course of those years, the ideal path forward lays the groundwork for a DSO and prepares for nimble scaling and development as the landscape evolves. As such, our assessment does not identify the model with the absolute greatest value quantitatively but provides a qualitative comparison of the cost and benefit of a representative set of archetypical DSO models. This assessment can be used as a guide for navigating the complex timing of introducing a DSO model in Ontario given the strength of market signals and the tradeoffs between different models. The following reflections can inform the OEB as it continues its engagement with respect to DSO capabilities.

In the present, our analysis found qualitative evidence to support some DSO use cases. Further (quantitative) evidence is desirable since the evidence was derived from LDC interviews, and this evidence shows DSO use cases and capability vary across the LDCs interviewed.

Looking to the future, the collective adoption of uniform DSO capability can maximise the benefits of DSO by maximising the routes to market for DER flexibility and building the supply side confidence that encourages investments in flexibility. This confidence can lead to a liquid, reliable, and economic market. Additionally, uniformity in coordinative processes and flexibility services ensures efficient deployment of flexibility, lowering the cost of market design, facilitation, and entry.

Preparing for that future is complicated. As the distribution system conditions change, so do the costs and benefits of a DSO. In this dynamic context, it is critical to monitor key system indicators: (1) the emergence of DSO use cases, (2) the (timely) development of DSO capabilities and functionality, and (3) the design and establishment of reliable, liquid markets (if warranted) for flexibility services.

While monitoring conditions, the OEB can use the insights from our model comparison to consider additional strategies. The Regulated DSO Model has comparatively low cost and might provide a safe test bed for a regulated flexibility mechanism, even if, over the long-term, the benefits it can deliver are limited. The DP-DSO, MF-DSO, and TDSO Models are more costly but could maximise potential once flexibility markets are in place.

Ontario does not need to select a preferred model at this stage. Even in the absence of a more quantitative assessment, developing the core functionality and capabilities to forecast, manage, and deploy DERs has little downside and these kinds of "low regret activities" could begin right away. Additionally, work can start on the design and standardization for DER flexibility products and services. As the urgency of market signals increases, the OEB should consider funding flexibility market capabilities.

Even amid an evolving market and a range of dynamic variables, the OEB can prepare for a DSO now without prematurely overcommitting or overinvesting. Setting long-term goals, remaining flexible in the pursuit of those goals, testing strategies within the existing framework, and investing in low regret activities that support several potential futures can all balance the duelling needs of DSO development: preparation and patience.

APPENDIX A. DEFINITIONS OF DESIGN FEATURES & VARIANTS

Table A-1. Business separation

ID -V	Variations	Definition
1.1	DNO-DSO horizontally integrated	Under the status quo option, the DNO and DSO functions are part of the same organization with no substantial separation or barriers between the two.
1.2	Hybrid option - some activities are separated (ring-fencing)	Under the ring-fencing governance model, the DNO and DSO functions are part of the same organization, but stricter business separation rules and measures are put in place including: ▪ Information separation, e.g., restrictions on accessing IT systems and confidential information; ▪ Separation of employees and staff such that staff do not work both inside and outside the ring-fenced function ▪ Physical separation such that staff are not working amongst other staff outside the ringfence. This requires, for example, rearranging office space, partitioning offices, and placing the ring-fenced team in a secure and separate work area
1.3	Legal separation	Creation of two entirely separate businesses and legal entities to host DNO functions and DSO functions. Under this arrangement, ownership of the DSO and DNO functions would remain within the same ownership group. The DSO should have operational independence to make real-time decisions for the distribution system without undue influence from other entities. This ensures agility in responding to system events and optimizing grid performance. DSO's independence and the responsibilities that will need to be undertaken under a legal separation scenario are explored in detail under TDSO.
1.4	Ownership separation or ownership unbundling	Ownership unbundling means the full unbundling of the DSO and DNO, through which the DSO activities and functions are divested from the DNO's ownership group, and strict rules and regulations apply such that the DNO or its affiliated businesses cannot perform any DSO-related functions or activities. In practice, it requires full separation of assets, staff, and technical and financial resources. In addition, DSOs could face a competitive procurement for X-year licenses to operate the grid (like DNO licenses in some countries).

Table A-2. Functional separation

ID -V	Variations	Definition
2.1	Narrow DSO Separation	Under a Narrow arrangement, the DSO would be solely responsible for the market and commercial arrangements associated with securing flexibility, communicating system requirements, and recording data concerning flexibility requirements.
2.2	Wider DSO Separation	Under a Wider arrangement, the DSO would be responsible for all activities described under the "Narrow" option above but would also take an active role in evaluating system solutions by identifying and defining constraints, assessing potential flexibility requirements, and identifying the most cost-effective solutions from flexibility, asset build, or smart options.
2.3	Widest DSO Separation	Under the Widest DSO separation option, the DSO would be responsible for all network planning, operation, and market facilitation functions that can be identified. In practice, the DSO would be responsible for all activities described above, including managing and dispatching operational flexibility, as well as being responsible for distribution system charges and settlement.

Table A-3. Hierarchy

ID -V	Variations	Definition
3.1	1DNO-1DSO in a license area	There is one DSO in each of the current licensed DNO areas. For Ontario, this would mean ~60 DSO licensed areas.
3.2	xDNOs-1DSO across Ontario	There is 1 DSO across Ontario with the same licenced area as the IESO. There is n (undefined number of) DSOs across Ontario, with the same licensed area as the IESO. n=1 where 1 DSO exists, n>1 where DSO can be offered as a service.
3.3	xDNOs-IESO	Integrate some or all the DSO functions with the provincial IESO. Hence, this option means full ownership, unbundling of the DSO from the DNO, and consolidation of all DSO functions into the IESO. This would result in the DSO function being divested from the DNO group and fully merged through acquisition into the IESO.
3.4	DSO-DSO coordination	This variation refers to a hierarchy of DNOs in the distribution grid (e.g., 1 DNO on lower voltage levels, 1 DNO on higher voltage levels). This could lead to a hierarchy of DSOs as well, depending on the preferred

ID -V	Variations	Definition
		option within 2.1, 2.2, and 2.3 - including additional DSO-DSO coordination.

Table A-4. Ownership of flexible resources

ID -V	Variations	Definition
7.1	DSO & market	DSO owns Flexible Resources, and these assets can participate in the markets/ flexibility mechanisms. The DSO can provide services to the market, IESO, or other DSOs by operating the Flexible Resources.
7.2	DSO & non-market	DSO owns Flexible Resources, and these assets are not allowed to participate in markets/ flexibility mechanisms.
7.3	3rd party	3rd party owns Flexible Resources and can both provide services to DSO/IESO and participate in markets.

Table A-5. Flexibility mechanisms

ID -V	Variations	Definition
4.1	Market-based	A competitive market-based mechanism that is open to Dx flexibility providers. The market is operated within a DSO-licenced area, which represents a single bidding zone.
4.2	Bilateral Agreements	The DSO procures flexibility via bilateral agreements with each provider.
4.3	Active Management of flexible assets	The DSO manages the assets via active network management mechanisms.
4.4	Rule-based (Regulated Cost-Based mechanism)	Driven by regulation, mandatory participation is required by all generators/DERs connecting to the network to respond to curtailment instructions, and return generators are compensated by a regulated price.
4.5	Nodal market - through	Nodal pricing represents a market design where every node in the electricity grid is a separate bidding zone, and all (relevant) grid constraints are considered in the market clearing algorithm, also known as Locational Marginal Pricing. In this scheme, the price at each node represents the

ID -V	Variations	Definition
	wholesale mechanism	locational value of energy, which includes the cost of the energy and the cost of delivering it. Whilst typically only applied at the wholesale market level, the concept can also be introduced (sufficiently high) in the distribution grid.

Table A-6. Flexibility market procurement and dispatch

ID -V	Variations	Definition
5.1	DSO Coordinates DERs and Local Flex Market	The DSO acts as a neutral market facilitator. It procures services for its local area, offering services to the IESO and to other DSOs in other regions.
5.2	IESO Coordinates DERs and Local Flex Market	IESO coordinates the procurement (and dispatch) of flexibility services. DSO submits requirements to the IESO. IESO to optimise procurement for Tx and Dx needs.
5.3	Independent Market Facilitator (IMF)	Service providers offer flexibility services to the IMF via a common platform. IMF considers and optimises these services against ESO and DSO needs. IMF dispatched DER via the platform. ESO maintains an existing role in procuring national and regional wholesale market services either from Tx customers or via IMF. No role for the DNO.
5.4	IESO - DSO coordinate (dual participation)	IESO procures and dispatches services for national needs and regional wholesale market requirements. DSO procures and dispatches flexibility resources connected to the distribution network for the local market. There's coordination to ensure efficient procurement and dispatch decisions and to optimise procurement and dispatch and conflict avoidance.

Table A-7. System coordination and operation

ID -V	Variations	Definition
6.1	DSO lead	DSO manages flow according to predefined limits; DSO is the leading regional response in major emergencies through the black start capability of DERs.
6.2	IESO-DSO joint coordination	IESO has its own control room, as do DSOs; coordination is required such as the coordination of emergency restoration options from DER.

ID -V	Variations	Definition
6.3	IESO lead	IESO lead role in managing provincial security, e.g., black start from DERs. Network and system responsibility are the same as 7.2.
6.4	Independent Market Facilitator (IMF)	The IMF would communicate with all SOs to advise on flexibility actions planned and taken, with accountability for network reliability residing with the appropriate SO. In the event of a system emergency, the operation of the Flexibility Coordinator's common platform would cease, and DSOs and the ESO would work together to resolve the issue before the platform operation recommenced.
6.5	No coordination	Status quo, where there is no coordination.

Table A-8. Network design & development

ID -V	Variations	Definition
8.1	Long-term planning	This variation is strongly related to principle 3 (functional separation). In the widest DSO separation, the DSO would be fully responsible for the long-term planning of the network and would instruct the DNO to implement the results of this activity. In the narrowest DSO separation, the DNO would be responsible, yet would take the DSO capabilities (and costs) into account, e.g., comparing grid reinforcements vs. non-wires solutions.
8.2	Connecting existing/ new customers	This variation is strongly related to principle 3 (functional separation). In the widest DSO separation, the DSO would be fully responsible for connection management and would instruct the DNO to create (or upgrade) the connection according to the results of this activity. In the narrowest DSO separation, the DNO would be responsible, yet would take the DSO capabilities (and costs) into account, e.g., considering non-wires solutions when the connection request is situated in a congested grid.
8.3	Outage planning	This variation is strongly related to functional separation. In the widest DSO separation, the DSO would be fully responsible for outage planning and would instruct the DNO to perform the resulting fieldwork. In the narrowest DSO separation, the DNO would be responsible, yet would take the DSO capabilities (and costs) into account, e.g., considering non-wires solutions when an outage would jeopardise n-1 safe operations.

APPENDIX B. DEFINITIONS OF ROLES

Table B-1 below shows the definitions of roles. The purple rows mean "existing role", and the green rows mean "new role".

Table B-1. Definition of roles

Role	Description
Aggregator	DERs and demand customers. As part of this initiative, we have identified 2 variants of an Aggregator: - **Commercial Aggregator:** This is the aggregator that performs the aggregated activities with commercial interest in those. The aggregator is compensated for providing these activities and takes risks regarding how markets operate. - **Non-Commercial Aggregator:** This is a regulated entity (like LDCs) that only facilitates communication flows and DER market participation. The non-commercial aggregator could provide services to IESO, but the settlement for the DERs is performed by the IESO. The non-commercial aggregator does not have any commercial interests in dispatch activities.
Ancillary services provider (ASP)	A market participant with reserve-providing units or reserve-providing groups can provide balancing services to IESOs. The ASP is the trading counterparty through which the Aggregator provides Balancing Services to the IESO. ASPs are contracted by the IESO and are responsible for procuring balancing energy.
Capacity service provider	A party that provides adequacy services to the IESO. This role is like the ASP and CMSP roles and is applicable for adequacy services only.
Congestion management service provider	A party that provides constraint management to a DSO or the IESO. In the provision of its services, the CMSP takes on specific responsibilities in communicating and coordinating flexibility transactions to effectively manage constraints between DSOs and/or the IESO.
DER owner	Owner of small-scale power generation, storage technologies, and end-use electricity consumers (e.g., industrial and commercial) with the ability to flex their demand (i.e., demand-side response) that are directly connected to the electricity distribution network. Participate in the wholesale market either directly or via an aggregator.
Dispatchable generators	Dispatchable generators submit offers to supply electricity in specific quantities and prices for each hour of the day. They can adjust the amount

Role	Description
	of electricity they generate in response to dispatch instructions issued as often as every five minutes by the IESO.
Dispatchable loads	Large energy consumers, also known as loads, can submit bids to purchase electricity. Dispatchable loads can adjust their power consumption in response to instructions arriving as often as every five minutes from the IESO.
Distribution Network Operator (DNO)	Owns and operates physical distribution assets and provides access to the distribution network to DERs and customer-load.
Distribution System Operator (DSO)	The natural or legal entity responsible for operating the distribution system in each area and, where applicable, its interconnections with other systems.
Electricity System Operator	Monitors the energy needs of the province in real time – 24 hours a day, 7 days a week – balancing supply and demand of the transmission system, planning for the province's future system needs, and developing wholesale electricity markets.
Flexibility market/ mechanism operator	A party that is responsible for administering the flexibility procurement in a flexibility market and the operation of any other flexibility mechanisms when markets are not available (e.g., regulated congestion management).
Government (Ministry of Energy)	Sets and monitors policies and government objectives that facilitate the energy transition.
Non-dispatchable generator	A non-dispatchable generator is one that typically has little control over its fuel source, such as a small hydro generator on a river, and cannot respond to five-minute signals in the market. Non-dispatchable generators are paid the Hourly Ontario Energy Price (HOEP).
Non-dispatchable loads	Non-dispatchable loads or consumers draw electricity from the IESO-controlled grid to meet their needs, regardless of the price, and cannot respond to five-minute signals in the market. Non-dispatchable loads pay the HOEP. A local distribution company is an example of a non-dispatchable load.
Real-time energy market operator	Operates the wholesale market in both day-ahead and real-time. Receives bids/offers and issues schedules for capacity, energy, and ancillary services.

Role	Description
Real-time energy market provider	A party that participates in the wholesale market and provides energy services to IESO.
Regulator (OEB)	Responsible for regulating the electricity and gas sector in the public interest and ensuring fair, transparent, and competitive market operation.
Competitive Retailer (or supplier)	Sources and supplies energy to end-users, manages (hedges) delivery and imbalances risks, and invoices its customers for energy. This term refers to only a small number of competitive retailers that are not LDCs in Ontario.
Standard Service Supplier (SSS)	Entity (currently LDCs) that sells power to end-use consumers who do not choose to buy electricity from a competitive electricity retailer under a contract as per the Standard Supply Service Code (SSSC). The provider of SSS is also responsible for billing consumers for the power that they consume. Since SSS is provided on a pass-through basis, LDCs take on no risk and are not permitted by the OEB to profit.
Settlement Agent (or Allocation Respon sible party)	A party that establishes and communicates the actual electricity volumes that are consumed and produced per settlement period within a certain metering area.
Transmitter	Owns, maintains, and operates the assets that transmit power between bulk resources and the distribution system.

APPENDIX C. DSO ACTIVITIES ANALYSIS BY FUNCTION

To describe how the functions would differ per DSO model, we performed an analysis that described the various activities per DSO function. For each activity, we determined if that activity was already in place in the Ontario market or if that activity would be new once the DSO model was implemented. We also indicated enhanced activities, which implies that the basic activity is in place; however, in a DSO world, an additional task will need to be performed by the associated role. Please note that the status of "existing, enhanced, new" activity does not change per model, but what differs per model is whether the activity applies to each model or not.

Existing = existing activity currently operated by existing actors. It can be performed by the DSO, depending on the DSO model.

Enhanced = enhanced activity will facilitate and support the role of DSO. It can be performed by the DSO, depending on the DSO model.

New = new activity that is required to facilitate and support the role of the DSO. It can be performed by the DSO, depending on the DSO model.

Table C-1. Distribution Network Planning & Development – Activities

ID-A	Activities	Existing/ Enhanced/New
1.1	Network planning/Outage Maintenance	Existing
1.2	Long-term forecasting demand and generation, including DERs	Enhanced
1.3	Identify capacity requirements on the distribution network, including analysis of DER hosting capacity / Assess distribution system needs, including flexibility requirements	Enhanced
1.4	Emergency response planning, including update of planning criteria to account for loss of DER used for distribution services	Enhanced
1.5	Invest in the distribution system solutions, including flexibility, asset builds, or smart solutions	Enhanced
1.6	Deliver the new network investment	Enhanced
1.7	Evaluate system solutions, including solutions from flexibility, asset build, or smart solutions	New
1.8	Co-ordinate with the IESO and Transmitters to identify whole electricity system solutions and support regional planning	New

Table C-2. Distribution Planning & Network Investment - Roles

ID-A	Activities	Existing/ Enhanced / New	Regulated DSO					DP-DSO					TDSO					MF				
			LDC/ DNO	LDC/ DSO	IESO	FSP	Other / 3rd party	LDC/ DNO	LDC/ DSO	IESO	FSP	Other / 3rd party	LDC/ DNO	DSO	IESO	FSP	Other / 3rd party	LDC/ DNO	DSO	IESO	FSP	Other / 3rd party
1.1	Network planning/Outage Maintenance	Existing	X					X					X					X				
1.2	Long-term forecasting demand and generation, including DERs	Enhanced		X					X					X					X			
1.3	Identify capacity requirements on the distribution network, including analysis of DER hosting capacity / Assess distribution system needs, including flexibility requirements	Enhanced	X						X					X					X			
1.4	Emergency response planning, including update of planning criteria to account for loss of DER used for distribution services	Enhanced	X						X					X					X			
1.5	Invest in the distribution system solutions, including flexibility, asset builds or smart solutions	Enhanced	X	X				X	X				X	X				X	X			
1.6	Deliver the new network investment	Enhanced	X					X					X					X				
1.7	Evaluate system solutions, including solutions from flexibility, asset build or smart solutions	New		X					X					X					X			
1.8	Co-ordinate with the IESO and Transmitters to identify whole electricity system solutions and support regional planning	New		X	X				X	X				X	X				X	X		

Table C-3. Distribution Network Operation - Activities

ID-A	Activities	Existing/ Enhanced/New
2.1	Real-time network modelling, identification of network constraints	Existing
2.2	Switching, outage restoration, and distribution maintenance	Existing
2.3	Maintain and enhance the visibility of the distribution system, including LV connected DERs and behind-the-meter assets	Enhanced
2.4	Co-ordinate with embedded distributors, transmitter, IESO (and potential other DSOs) on real-time operating constraints, operation primacy on DER assets	Enhanced
2.5	Real-time data management and sharing with relevant parties (e.g., DER owners, IESO, embedded distributors)	Enhanced
2.6	Identify congestion alleviation requirements	Enhanced
2.7	Monitor ANM schemes	New
2.8	Operate ANM schemes	New

ID-A	Activities	Existing/ Enhanced/New
2.9	Communicate to DER owners operating constraints in real on near to real time (for example, for outage or operation in alternate system configuration)	New
2.10	Supply of grid-operational services using DER assets	New
2.11	Supply of grid-operational services using LDC/DNO assets	New

Table C-4. Distribution Network Operation - Roles

ID-A	Activities	Existing / Enhanced / New	Regulated DSO					DP-DSO					TDSO					MF				
			LDC/ DNO	LDC/ DSO	IESO	FSP	Other / 3rd party	LDC/ DNO	LDC/ DSO	IESO	FSP	Other / 3rd party	LDC/ DNO	DSO	IESO	FSP	Other / 3rd party	LDC/ DNO	DSO	IESO	FSP	Other / 3rd party
2.1	Real-time network modelling, identification of network constraints	Existing	X					X					X					X				
2.2	Switching, outage restoration and distribution maintenance	Existing	X					X					X					X				
2.3	Maintain and enhance visibility of distribution system, including LV connected DERs and behind-the-meter assets	Enhanced	X					X					X					X				
2.4	Co-ordinate with embedded distributors, transmitter, IESO (and potential other DSOs) on real-time operating constraints, operation primacy on DER assets	Enhanced	X		x			X		x				X	X				X	X		
2.5	Real-time data management and sharing with relevant parties (e.g. DER owners, IESO, embedded distributors)	Enhanced	X					X					X					X				
2.6	Identify congestion alleviation requirements	Enhanced		X					X					X					X			
2.7	Monitor ANM schemes	New	x					X						X					X			
2.8	Operate ANM schemes	New	x					X						X					X			
2.9	Communicate to DER owners operating constraints in real on near to real-time (for example for outage or operation in alternate system configuration)	New		X					X					X					X			
2.10	Supply of grid-operational services (Transmission and Distribution) using DER assets	New				X					X			X		X					X	
2.11	Supply of grid-operational services (Transmission and Distribution) using LDC/DNO assets	New		X					X					X					X			

Table C-5. Market/Mechanism Development - Activities

ID-A	Activities	Existing/ Enhanced/New
3.1	Define and (regularly) revisit services to be procured through distribution markets	New
3.2	Develop and, where possible, standardise terms & conditions for flexibility services	New
3.3	Develop and, where possible, standardise flexibility contractual processes	New
3.4	Develop and, where possible, standardise settlement processes	New
3.5	Develop and, where possible, standardise flexibility trading processes	New

ID-A	Activities	Existing/ Enhanced/New
3.6	Develop distribution market rules including for non-discriminatory access to distribution markets and, where required by the DER participation model, for facilitation of non-discriminatory access to IAM (for example, develop flexibility services stacking rules)	New
3.7	Providing information to enable third parties to evaluate prospective investments for DER services to the distribution	New
3.8	Market monitoring, compliance, and enforcement of distribution market rules.	New

Table C-6. Market/Mechanism Development - Roles

ID-A	Activities	Existing / Enhanced / New	Regulated DSO					DP-DSO					TDSO					MF				
			LDC/ DNO	LDC/ DSO	IESO	FSP	Other / 3rd party	LDC/ DNO	LDC/ DSO	IESO	FSP	Other / 3rd party	LDC/ DNO	DSO	IESO	FSP	Other / 3rd party	LDC/D NO	DSO	IESO	FSP	Other/ 3rd party
3.1	Define and (regularly) revisit services to be procured through distribution markets or the processes to activate flexibility via a regulated congestion mechanism.	New		X					X					X					X			
3.2	Develop and where possible standardise terms & conditions for flexibility services or rule-based mechanism.	New		X					X					X					X			
3.3	Develop and where possible standardise flexibility contractual processes for congestion mechanisms and markets	New		X					X					X					X			
3.4	Develop and where possible standardise settlement processes	New		X					X					X					X			
3.5	Develop and where possible standardise flexibility trading processes	New	N/A	N/A	N/A	N/A	N/A		X					X					X			
3.6	Develop distribution market rules including for non-discriminatory access to distribution markets and, where required by DER participation model, for facilitation of non-discriminatory access to IAM (for example develop flexibility services stacking rules)	New	N/A	N/A	N/A	N/A	N/A		X	X				X	X				X	X		
3.7	Providing information to enable third parties to evaluate prospective investments for DER services to connect to the distribution network	New	X					X						X					X			
3.8	Market monitoring, compliance, and enforcement of distribution market rules.	New					X					X					X					X

Table C-7. Distribution Market/Mechanism Operation – Activities

ID-A	Activities	Existing/ Enhanced/New
4.1	Developing updated cyber security requirements for DER providing services to the distribution system.	Enhanced
4.2	Depending on the DER participation model in IAM, aggregating DSO-activated DER for participation in IAM (i.e., at floor prices for DSO-activated capacity).	Enhanced
4.3	Depending on the DER participation model in IAM, aggregating non-DSO-activated DER for participation in IAM (i.e., as pass-through to IAM).	New
4.4	Translating network congestion into flexibility requirements	New

ID-A	Activities	Existing/ Enhanced/New
4.5	Impartially operating a local market for distribution services (excluding market for transaction of energy).	New
4.6	Decision-making on which assets should be activated	New
4.7	Control/dispatch the flexible assets	New
4.8	Operation and maintenance of distribution flexibility trading platforms	New
4.9	Manage and schedule DERs activation/ flexibility dispatch or curtailment signals in accordance with operating agreements, contracted services, or based on market signals.	New
4.10	Reviewing activation of DER to ensure such operation does not result in adverse distribution system impacts (including when DER is activated in accordance with a bilateral contract or due to participation in IESO-Administered Markets (IAM)).	New
4.11	For cases where DER is activated for distribution services, handling all metering, billing, and settlement.	New
4.12	For cases where DER is aggregated by the DSO for participation in IAM, handling all metering, billing, and settlement.	New
4.13	Assess and record flexibility providers' performance	New
4.14	Lead coordination on managing and dispatching flexibility with the IESO (and other parties)	New

Table C-8. Distribution Market/Mechanism Operation – Roles

ID-A	Activities	Existing / Enhanced / New	Regulated DSO					DP-DSO					TDSO					MF				
			LDC/ DNO	LDC/ DSO	IESO	FSP	Other / 3rd party	LDC/ DNO	LDC/ DSO	IESO	FSP	Other/ 3rd party	LDC/ DNO	DSO	IESO	FSP	Other/ 3rd party	LDC/ DNO	DSO	IESO	FSP	Other/ 3rd party
4.1	Developing updated cyber security requirements for DER providing services to the distribution system.	Enhanced		X					X					X					X			
4.2	Depending on DER participation model in IAM, aggregating DSO-activated DER for participation in IAM (i.e. at floor prices for DSO-activated capacity).	New	N/A	N/A	N/A	N/A	N/A				X			X							X	
4.3	Depending on DER participation model in IAM, aggregating non-DSO-activated DER for participation in IAM (i.e. as pass-through to IAM).	New	N/A	N/A	N/A	N/A	N/A				X			X							X	
4.4	Translating network congestion into flexibility requirements	New	X					X						X					X			
4.5	Impartially operating a local market for distribution services (excludes market for transaction of energy).	New	N/A	N/A	N/A	N/A	N/A		X					X					X			
4.6	Decision making on which assets should be activated for distribution market/mechanism operation	New		X					X					X					X			
4.7	Control the flexible assets	New		X							X					X					X	
4.8	Operation and maintenance of distribution flexibility trading platforms*	New	N/A	N/A	N/A	N/A	N/A		X					X					X	X		
4.9	Manage and schedule DERs activation/ flexibility dispatch or curtailment signals in accordance with operating agreements, contracted services, or based on market signals.	New		X				X						X					X			
4.10	Reviewing activation of DER to ensure such operation does not result in adverse distribution system impacts (including when DER is activated in accordance with a bilateral contract or due to participation in IESO-Administered Markets (IAM)).	New		X				X						X					X			
4.11	For cases where DER activated for distribution services, handling all metering , billing and settlement.	New		X				X						X					X			
4.12	For cases where DER aggregated by the DSO for participation in IAM, handling all metering, billing, and settlement*.	New	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		X						X		
4.13	Assess and record flexibility providers' performance	New	N/A	N/A	N/A	N/A	N/A	X						X					X			
4.14	Lead co-ordination on managing and dispatching flexibility with the IESO (and other parties)	New	X					X						X					X			

Table C- 9. Connections Provision - Activities

ID-A	Activities	Existing/ Enhanced/New
5.1	Provide fair and cost-effective distribution network access	Existing
5.2	Provide a range of connection options that meet customer requirements and system needs efficiently	Enhanced
5.3	Providing data to potential DER applicants to inform DER development, including related to system needs, forecasted curtailments, and historical curtailments	Enhanced
5.4	Studying, approving, and setting operating requirements for new DER connections	Enhanced
5.5	Facilitate queue management of DER connections	New
5.6	Own DERs	New

Table C- 10. Connections Provision – Roles

ID-A	Activities	Existing / Enhanced / New	Regulated DSO					DP-DSO					TDSO					MF				
			LDC/ DNO	LDC/ DSO	IESO	FSP	Other / 3rd party	LDC/ DNO	LDC/ DSO	IESO	FSP	Other / 3rd party	LDC/ DNO	DSO	IESO	FSP	Other / 3rd party	LDC/ DNO	DSO	IESO	FSP	Other / 3rd party
5.1	Provide fair and cost-effective distribution network access	Existing	X					X						X					X			
5.2	Provide a range of connection options that meet customer requirements and system needs efficiently	Enhanced	X					X						X					X			
5.3	Providing data to potential DER applicants to inform DER development, including related to system needs, forecasted curtailments, and historical curtailments	Enhanced	X					X						X					X			
5.4	Studying, approving, and setting operating requirements for new DER connections	Enhanced	X					X						X					X			
5.5	Facilitate queue management of DER connections	New	X					X						X					X			
5.6	Own DERs	New		X		X					X					X					x	

APPENDIX D. SYSTEM CONDITION ASSESSMENT

Based on DNV's experience, engagement to date, and publicly available studies, DNV compiled a list of use cases for DSO transition (Table D-1). Three of the six use cases were validated as relevant for the Ontario market and are the foundation for the system indicators assessment. That process is described in Section 4.

Table D-1. Use cases for DSO transition

Use case	Detail	LDC challenges	Role of DSO
Non-Wire Solution	Utilities can defer or avoid the high costs associated with building new transmission and distribution lines by using DERs	• Limited resources and cost • Aging infrastructure • DERs connection • Customer expectations	Connecting DERs while optimising network reinforcement
Congestion Management	Utilities can use DERs to manage local congestion on the network and connect more DERs while reducing DER curtailment.	• Electrification of demand • Cost of upgrades • Limited grid capacity/constraints • Operational complexity • DERs connection	Connecting DERs while maintaining grid resilience
Operational efficiency	DSO model leverages smart grid technologies, providing real-time visibility and control over the network. This helps in better managing the complexities of modern energy systems.	• Operational complexity • DERs connection • Customer expectations • Aging infrastructure	Maintain grid reliability and empower customers
Energy security of supply	As Canada transitions to Net Zero, the volume of DERs connecting to distribution networks is increasing while traditional generation assets are phasing out. DERs can provide flexibility services needed to	• DERs connection • Natural disasters and extreme weather • Financial constraints	DSO-IESO coordination Management of DERs, unlocking DERs benefits

Use case	Detail	LDC challenges	Role of DSO
	operate a future-proof, carbon-neutral system.		
Balancing generation and demand / reducing peak load	DERs are used to balance supply and demand, providing additional power and reducing the need for expensive and additional power during peak periods.	• Residual demand fluctuations • Technological integration • DERs connection	DSO-IESO coordination Management of DERs, unlocking DERs benefits
Decarbonisation and compliance with regulation	Utilities' commitment to achieve net-zero emissions. The DSO model is suited to manage the complexities of integrating DERs into the grid	• Regulatory and policy compliances	Management of DERs, unlocking DERs benefits

We developed a tool for each of the use cases to monitor system indicators. The suggested system indicators have been informed by DNV's experience helping develop DSO models in different jurisdictions (e.g., UK) as well as our familiarity with developments in other jurisdictions (e.g., Germany). Additionally, the indicators were informed by a review of existing literature on the system conditions that support the development of DSO models. The complete tool and analysis are found in APPENDIX D.

This tool serves as a guide for identifying key indicators rather than providing specific data or milestones from the Ontario energy system.

Based on the qualitative information from LDC interviews, DNV performed an aggregated, high-level scoring of system indicators across Ontario, assessing the viability and urgency of using DERs to provide NWSs in the Ontario electricity energy system.

- For each system indicator, the long-, mid-, and to short-term values indicate how urgently a transition to a DSO may be needed: the shorter the term, the more urgent the need.
- The following discussion details the assessment using **low**, **medium**, **medium-high**, and **high** values to describe the urgency of the system condition.

Non-Wire Solutions (NWS) Use Case

NWS refers to the use of flexibility to defer the investment required in physical network infrastructure. Studies have shown that the use of flexibility is unlikely to permanently remove the need for reinforcement, but the use of flexibility can allow works to be deferred so that required works can be staggered.

Table D-2. System indicators for NWS

	Description	Long-term	Mid-term	Short-term
DER penetration	High DER penetration offers the ability for networks to explore NWS and may start to create complexities that require it	Low, dispersed <10%	Variable across network 10-30%	High, concentrated >30%
Hosting Capacity	Where hosting capacity is limited, the ability to connect more DERs to the grid is limited. The greater the number of locations with reduced capacity across the network, the higher the urgency to intervene. NWS can help to reduce peak loads.	High capacity (>40%), few locations	Medium capacity (20-40%), several locations	Low capacity (<20%), many locations
Cost to reinforce*	The higher the cost to physically reinforce the network, the greater the benefit of avoiding such costs.	Low	Medium	High
Time to reinforce**	Similarly, the longer reinforcements take, the stronger the case for NWS.	Fast, Predictable	Medium	Slow, Risky
Connections queue***	Where queues are long, NWS can help to provide quicker (though limited) connections.	Short, queue decreasing in length	Medium, stable queue	Long, queue increasing in length

**Cost to reinforce will vary greatly depending on the utility and the project*
*** Supply chain, commodities prices, system access, skills & resources*
**** Connections queue lengths will vary from network to network. An important trend to understand is whether queue times are expected to increase, stay stable, or reduce*

Discussion of scoring

Qualitative evaluation of system indicators to determine viability of using of DER for NWS.

DER penetration – **high:** On the LDC networks with the highest penetration rates, DER penetration (measured by % peak output generated by DER) is approaching 50%. However, it should be recognised that DER penetration is highly variable across networks and even within networks. DER provision is highest in utility-scale and industrial uses and lower at residential levels but is expected to grow at the residential level with electric vehicle adoption.

Hosting capacity – **medium-high:** Capacity is restricted in several locations, and traditionally, reinforcement would be expected. LDCs reported that the list of reinforcements required is growing.

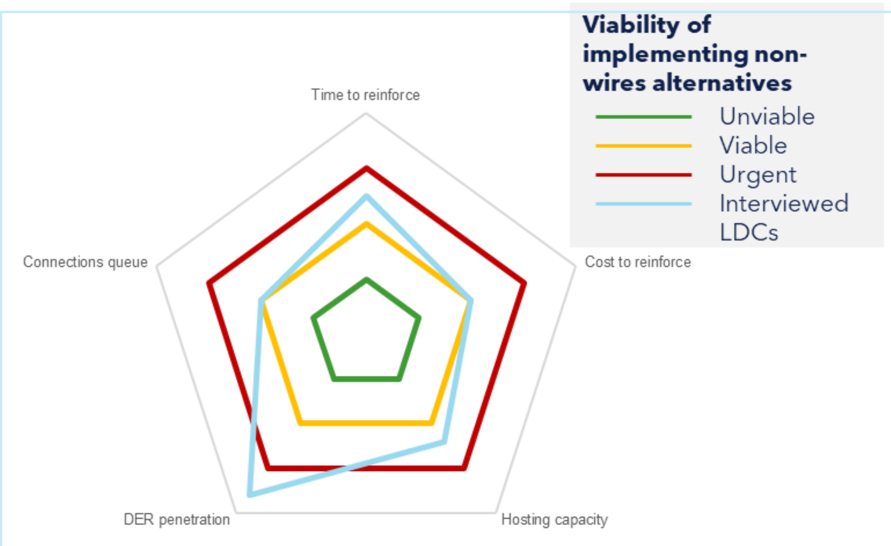
Cost to reinforce – **medium:** Not based on interviews as networks did not share costs due to commercial sensitivities. DNV has assumed this need to be at least medium based on the global pressure on power network supply chains and inflationary pressures driving up costs (e.g., availability of raw materials and key plant such as transformers).

Time to reinforce – **medium-high:** Firm timelines for reinforcement were not given. However, interviewees did state in some places that the list of reinforcements is getting longer and that the utilities are getting further behind. This fits with global trends where supply chain pressures and increased demand for connections are creating pressure on reinforcement timelines.

Connections queue – medium: Queues are generally understood to be manageable by LDCs. However, there is concern that the number of connection requests could increase, particularly if policies that support DER integration are introduced or expanded (e.g., IESO's Industrial Conservation Initiative, which focuses on providing demand response).

Figure D-1 is a visual representation of the viability and urgency of using DERs to provide non-wires solutions in Ontario, based on the criteria shown in Table D-2. NWS refers to the use of flexibility to defer the investment required in physical network infrastructure. Studies have shown that the use of flexibility is unlikely to permanently remove the need for reinforcement, but the use of flexibility can allow works to be deferred so that required works can be staggered. The larger the area occupied within the blue line, the greater the viability and urgency of implementing non-wires solutions within Ontario.

Figure D-1. Viability and Urgency for NWS



Congestion Management Use Case

The use of flexibility for distribution congestion management is the ability to adjust and manage the supply and demand of electricity to prevent or alleviate congestion on the grid through a variety of flexibility mechanisms, such as demand response services, the use of storage assets to store or discharge electricity, and flexibility markets.

Table D-3. System indicators for Congestion Management

	Description	Long-term	Mid-term	Short-term
DER penetration	Higher DER penetration offers a greater potential for procuring congestion management services through a variety of mechanisms.	Low, dispersed <10%	Variable across network 10-30%	High, concentrated >30%

	Description	Long-term	Mid-term	Short-term
Cost of DER curtailment	Networks that currently incur high curtailment costs have a greater incentive to reduce these costs. Depending on the agreement between the network and system operators and the asset owners, there may be considerable costs generated from curtailing customers. In addition, curtailment can drive up energy prices. Therefore, to understand the impact of curtailment, these figures should be aggregated and assessed on a per customer basis. It is not possible to quantify these costs across LDCs as the figures are dependent on the number of customers and the generation sources in the region.	C$/kWh (low)	C$/kWh (med)	C$/kWh (high)
Network issues	If DER issues (e.g., thermal, voltage) are prevalent across large parts of the network, the benefit of addressing the issues is greater than if they are highly localised. Issues can include high transformer loading (80%+), high line loading (80%+) and voltage deviations (> +/-0.1Hz)	Specific locations Limited to <5% network	Mix 5-15% network	All over the network 15%+ network
Levels of DER curtailment	A high level of DER curtailment suggests that there are high levels of congestion on the network and that there could be higher benefits from addressing these issues. Where curtailment can be reduced, this provides a benefit to connectees as they can export their power for longer.	Infrequent, short <5%*	Moderate 5-15%*	Frequent, long 15%+*

Discussion of scoring
Qualitative evaluation of system indicators to determine viability of using of DER for congestion management. The scoring does not reflect the situation across each network, or even the whole of individual networks, but reflects the situation on parts of the Ontario distribution network.

DER penetration – **high**: On the LDC networks with the highest penetration rates, DER penetration (measured by % peak output generated by DER) is approaching 50%. However, it should be recognised that DER penetration is highly variable across networks and even within networks.

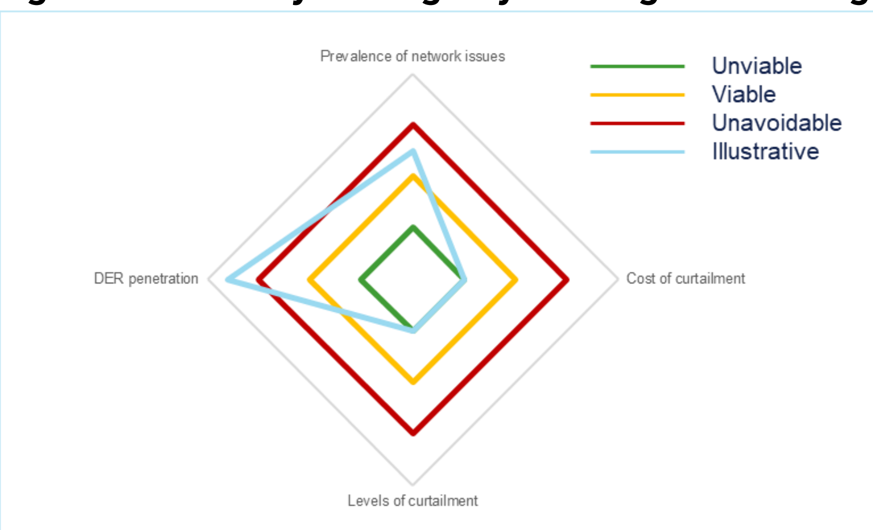
Cost of curtailment – **low**: Curtailment costs have not been explored and were not discussed in the interviews. They have, therefore, been given a default score of low.

Prevalence of network issues – medium-high: Most LDCs interviewed identified that there is an increasing risk of network issues (e.g., reduced reliability, thermal constraints, voltage constraints, short-circuit risks) across networks due to ageing assets and an increasing number of DERs connecting. These issues tend to be intensified and concentrated in parts of the network where there are higher levels of utility-scale DERs. Capital expenditure plans are in place to upgrade and replace assets, but this takes time.

Levels of curtailment – **low**: Curtailment at the distribution level was not described as a major concern by the LDCs interviewed, and at the wholesale market level, the latest available figures show curtailment of 0.68% against a target of 1.74%.[1]

Figure D-2 is a visual representation of the viability and urgency of using DERs to provide congestion management in Ontario. The larger the area occupied within the **blue** line, the greater the viability and urgency of using DERs to implement congestion management within Ontario.

Figure D-2. Viability and Urgency for Congestion Management



Operational Efficiency Use Case

Operational efficiency refers to the optimisation of business processes in the day-to-day running of the network while maximising network reliability and customer satisfaction and reducing costs.

Table D-4. System indicators for Operational Efficiency

	Description	Long-term	Mid-term	Short-term
DER penetration	Higher DER penetration offers a greater potential for operational efficiency on the network through a variety of mechanisms, such as voltage and load control.	Low, dispersed, <10%	Variable across network 10-30%	High, concentrated >30%
DER / Network visibility	Higher network visibility allows for greater potential operational efficiency from DERs. Visibility is measured through a variety of metrics: % coverage of (relevant) network – monitoring is more important on parts of the network which have lower capacity; maturity and granularity of data source (e.g., real-time monitoring v. reliance on forecasts); voltage level coverage.	Real-time monitoring High levels of smart meter penetration (75%+) Coverage of all voltage levels	Combination of real-time monitoring and forecasting Developing smart meter penetration (50 – 75%) Higher voltages	Heavily reliant on forecasts Low smart meter penetration (<50%) Limited to highest voltages
Number of Customer interruptions*	An OEB scorecard metric – a higher number of customer interruptions suggests a greater opportunity for improving operational efficiency.	Low	Medium	High
Duration of customer interruptions*	An OEB scorecard metric – the longer customer interruptions, the greater the potential benefit from greater operational efficiency – e.g., through locating and repairing faults quicker	Low	Medium	High
Network issues	If DER issues (e.g., thermal, voltage) are prevalent across large parts of the network, the benefit of addressing the issues is greater than if they are highly localised. Issues can include high transformer loading (80%+), high line loading (80%+) and voltage deviations (> +/-0.1Hz)	Specific locations Limited to <5% network	Mix 5-15% network	All over the network 15%+ network

	Description	Long-term	Mid-term	Short-term
Total cost per customer*	Higher costs per customer could be an indicator that a network is operating inefficiently, particularly if their costs are rising in contrast to other operators	C$ / customer (low)	C$ / customer (med)	C$ / customer (high)

These metrics will vary greatly depending on the network and the geographies in which they operate; therefore, it is not possible to quantify them. For example, a rural LDC is likely to have more customer interruptions as their lines/cables are more likely to be above ground than an urban LDC, leaving them more exposed to adverse conditions. Additionally, once there has been a fault, it is likely to take the LDC longer to mobilise and get a repair team to the site of the problem. This is reflected in OEB's electricity distributor scorecards, in which these metrics vary from distributor to distributor.

Discussion of scoring

Qualitative evaluation of system indicators to determine viability of using of DER for operational efficiency.

DER penetration – **high**: On the LDC networks with the highest penetration rates, DER penetration (measured by % peak output generated by DER) is approaching 50%. However, it should be recognised that DER penetration is highly variable across networks and even within networks.

Network visibility – medium-high: Most LDCs stated problems with network visibility. In the best case, there was 100% SCADA visibility of assets larger than 250kW, but at smaller asset sizes and residential properties, visibility was severely limited. One LDC has only just started their AMI rollout.

Number of customer interruptions – **medium-high**: 31% of LDCs in Ontario negatively exceeded their target for the average number of times that power to a customer was interrupted in 2023.

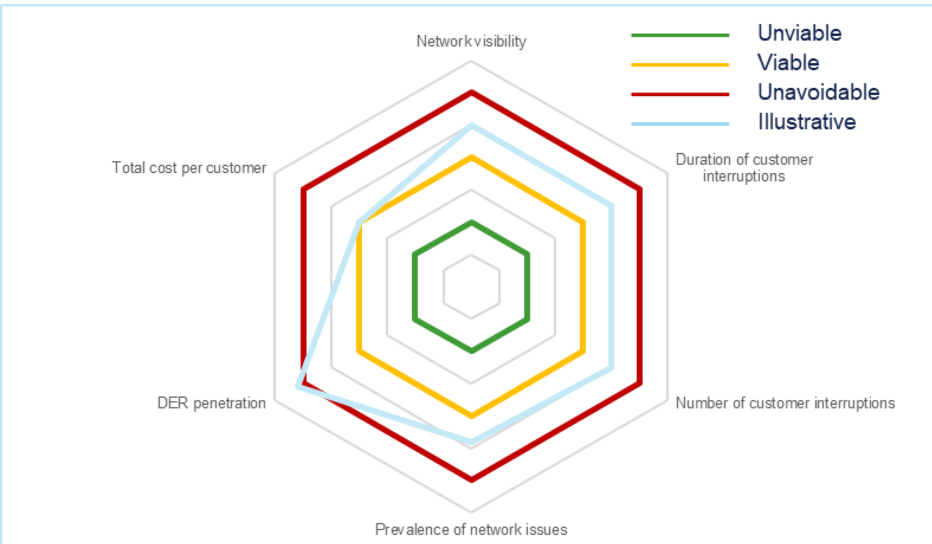
Duration of customer interruptions – **medium-high**: 35% of LDCs in Ontario negatively exceeded their target for the average duration of interruptions to customer power supply in 2023.

Prevalence of network issues – medium-high: Most LDCs interviewed identified that there is an increasing risk of network issues (e.g., reduced reliability, thermal constraints, voltage constraints, short-circuit risks) across networks due to ageing assets and an increasing number of DERs connecting. Capital expenditure plans are in place to upgrade and replace assets, but this takes time.

Cost per customer – **medium**: 15% of networks had a total cost per customer of over $1,000. In addition, there is a high correlation between those networks with high costs per customer and those networks whose costs are 10% or higher than predicted, indicating a reasonable level of inefficiency.

Figure D-3 is a visual representation of the viability and urgency of using DERs to provide congestion management in Ontario. The larger the area occupied within the **blue** line, the greater the viability and urgency of using DERs to create operational efficiency within Ontario.

Figure D-3. Viability and Urgency for Operational Efficiency



APPENDIX E. ASSESSMENT ASSUMPTIONS AND COSTS BY FUNCTION

DNV assessed the cost of implementing each activity within the five identified functions for each of the DSO models. The costs are relative costs, taking into consideration the systems, data, and skills required to implement each activity.

How have we determined the costs?

The logic has been applied consistently throughout the exercise, but in some cases, there have been clear exceptions where costs would be notably higher or lower than the logic would suggest.

- If **existing** capability = no cost
- If **enhanced** capability:
  - Regulated DSO = low (small improvement to existing capability with no extra personnel needed)
  - DP-DSO = low / medium (depending on functions requiring a separate team due to transparency and impartiality requirements)
  - MF-DSO = low / medium (depending on functions requiring a separate team due to transparency and impartiality requirements)
  - TDSO = medium/high (requires transfer of systems/skills to new DSO entity or entirely new systems and skills)
- If **new** capability = high cost
  - First implementation of a system = high cost. However, where the same system is needed to deliver other activities, the cost of the implementation is disregarded to avoid double accounting.
- Activities that require no new systems = low or medium cost with some explicit exceptions
- The cost considers CAPEX (implementation of technologies and integrations) and OPEX (resources); however, it does not take into consideration the overheads resulting from the business change (HR, finance, IT functions, etc).
- If **N/A** capability = No cost

DNV

Table E-1. Distribution Network Planning & Development

	Activities	Capability status	Model 1 (regulated DSO)		Notes	Model 2 (dual participation)		Notes	Model 3 (total DSO)		Notes	Model 4 (NMF)		Notes
			DNO Cost	DSO Cost		DNO Cost	DSO Cost		DNO Cost	DSO Cost		DNO Cost	DSO Cost	
1.1	Network planning / outages and maintenance	Existing	No cost	No cost	Existing DNO capability	No cost	No cost	Existing DNO capability	No cost	No cost	Existing DNO capability	No cost	No cost	Existing DNO capability
1.2	Long-term forecasting demand and generation, including DERs	Enhanced	No cost	Low	Enhanced capability but only required within the DSO	No cost	Medium	Transfer of existing capability to DSO resulting in costs to set up the capability for the DSO.	No cost	Medium	Transfer of existing capability to DSO resulting in costs to set up the capability for the DSO.	No cost	Medium	Transfer of existing capability to DSO resulting in costs to set up the capability for the DSO.
1.3	Identify capacity requirements on the distribution network, including analysis of DER hosting capacity / assess distribution system needs, including flexibility requirements	Enhanced	Medium	No cost	New system implementation (System coordination tool)	No cost	High	New system implementation (System coordination tool) and new team set up	No cost	High	New system implementation (System coordination tool) and new team set up	No cost	High	New system implementation (System coordination tool) and new team set up
1.4	Emergency response planning, including update of planning criteria to account for loss of DER used for distribution services	Enhanced	Low	No cost	The DNO already has the resources for doing this and there is minimal coordination required	No cost	Medium	Transfer of existing capability to DSO resulting in costs to set up the capability for the DSO.	No cost	Medium	Transfer of existing capability to DSO resulting in costs to set up the capability for the DSO.	No cost	Medium	Transfer of existing capability to DSO resulting in costs to set up the capability for the DSO.
1.5	Invest in the distribution system solutions, including flexibility, asset builds or smart solutions	Enhanced	Low	High	New capabilities required: Dynamic Line Rating (DNO) – assuming already undertaken ANM (DSO) – Assume a high number of schemes and communication infrastructure	Low	High	New capabilities required: Dynamic Line Rating (DNO) – assuming already undertaken ANM (DSO) – Assume a high number of schemes and communication infrastructure	Low	High	New capabilities required: Dynamic Line Rating (DNO) – assuming already undertaken ANM (DSO) – Assume a high number of schemes and communication infrastructure	Low	High	New capabilities required: Dynamic Line Rating (DNO) – assuming already undertaken ANM (DSO) – Assume a high number of schemes and communication infrastructure
1.6	Deliver the new network investment	Enhanced	Low	No cost	Requires coordination	Low	No cost	Requires coordination	Low	No cost	Requires coordination	Low	No cost	Requires coordination
1.7	Evaluate system solutions, including solutions from flexibility, asset build or smart solutions	New	No cost	Medium	No market, requires new tool and coordination	No Cost	High	Requires new tools and coordination (inc. Market Platform)	No cost	High	Requires new tools and coordination (inc. Market Platform)	No cost	High	Requires new tools and coordination (inc. Market Platform)
1.8	Co-ordinate with the IESO and Transmitters to identify whole electricity system solutions and support regional planning	New	No cost	Low	Tool already accounted for in activity 1.3, requires coordination with IESO	No Cost	Low	Tool already accounted for in activity 1.3, requires coordination with IESO	No cost	Medium	Tool already accounted for in activity 1.3, requires coordination with IESO *and* new team	No cost	Low	Tool already accounted for in activity 1.3, requires coordination with IESO. (i.e. similar to Model 2).

Table E-2. Distribution Network Operation

	Activities	Capability status	Model 1 (regulated DSO)		Notes	Model 2 (dual participation)		Notes	Model 3 (total DSO)		Notes	Model 4 (NMF)		Notes
			DNO Cost	DSO Cost		DNO Cost	DSO Cost		DNO Cost	DSO Cost		DNO Cost	DSO Cost	
2.1	Real-time network modelling, identification of network constraints	Existing	No cost	No cost	Existing activity conducted by DNO. No requirement for DSO to be involved.	No cost	No cost	Existing activity conducted by DNO. No requirement for DSO to be involved.	No cost	No cost	Existing activity conducted by DNO. No requirement for DSO to be involved.	No cost	No cost	Existing activity conducted by DNO. No requirement for DSO to be involved.
2.2	Switching, outage restoration and distribution maintenance	Existing	No cost	No cost	Existing activity conducted by DNO. No requirement for DSO to be involved.	No cost	No cost	Existing activity conducted by DNO. No requirement for DSO to be involved.	No cost	No cost	Existing activity conducted by DNO. No requirement for DSO to be involved.	No cost	No cost	Existing activity conducted by DNO. No requirement for DSO to be involved.
2.3	Maintain and enhance visibility of distribution system, including LV-connected DERs and behind-the-meter assets	Enhanced	Medium	No cost	Existing activity conducted by DNO, but effort required expected to grow with more DERs. DSO not involved	Medium	No cost	Existing activity conducted by DNO, but effort required expected to grow with more DERs. DSO not involved	Medium	No cost	Existing activity conducted by DNO, but effort required expected to grow with more DERs. DSO not involved	Medium	No cost	Existing activity conducted by DNO, but effort required expected to grow with more DERs. DSO not involved
2.4	Co-ordinate with embedded distributors, transmitter, IESO (and potential other DSOs) on real-time operating constraints, operation primacy on DER assets	Enhanced	Medium	No cost	Tools already accounted for in function DPND Existing activity conducted by DNO but requires IESO coordination. DSO not involved.	Medium	No cost	Tools already accounted for in function DPND Existing activity conducted by DNO but requires IESO coordination. DSO not involved.	No cost	High	DSO must take on new activities with extensive real-time resource and coordination requirements	No cost	High	DSO must take on new activities with extensive real-time resource and coordination requirements
2.5	Real-time data management and sharing with relevant parties (e.g. DER owners, IESO, embedded distributors)	Enhanced	Low	No cost	Tools, skills accounted for in 2.4	Low	No cost	Tools, skills accounted for in 2.4	Low	No cost	Tools, skills accounted for in 2.4	Low	No cost	Tools, skills accounted for in 2.4
2.6	Identify congestion alleviation requirements	Enhanced	No cost	Medium	Systems accounted for in DPND. Activity inherited from DNO but with additional data handling required.	No cost	Medium	Systems accounted for in DPND. Activity inherited from DNO but with additional data handling required.	No cost	Medium	Systems accounted for in DPND. Activity inherited from DNO but with additional data handling required.	No cost	Medium	Systems accounted for in DPND. Activity inherited from DNO but with additional data handling required.

Table E-3. Market / Mechanism Development

2.7	Monitor Active Network Management (ANM) schemes	New	Low	No cost	Systems accounted for in DPND. Requires expansion of existing ANM provision but can be carried out by existing teams with new training	Low	No cost	Systems accounted for in DPND. Requires expansion of existing ANM provision but can be carried out by existing teams with new training	No cost	Medium	Systems accounted for in DPND. Requires new teams to be set up for the DSO	No cost	Low	Systems accounted for in DPND. Requires team from LDC to moved to DSO.
2.8	Operate ANM schemes	New	Low	No cost	Uses the people and systems established in 2.7	Low	No cost	Uses the people and systems established in 2.7	No cost	Low	Uses capabilities set up in 2.7	No cost	Low	Uses capabilities set up in 2.7
2.9	Communicate to DER owners operating constraints in real or near-to-real-time (for example for outage or operation in alternate system configuration)	New	No cost	Low	Systems accounted for in DPND. Network constraints understood in other activities but these must be communicated to DER owners – most likely using existing channels	No cost	Low	Systems accounted for in DPND. Network constraints understood in other activities but these must be communicated to DER owners – most likely using existing channels	No cost	Medium	Systems accounted for in DPND. Requires new teams to be set up for the DSO	No cost	Low	Systems accounted for in DPND. Network constraints understood in other activities, but these must be communicated to DER owners – most likely using existing channels
2.10	Supply of grid-operational services (Transmission and Distribution) using DER assets	New	No cost	Low	Requires some coordination and communication with DER providers. Coordination incurs a small cost but does not require new systems.	No cost	Low	Requires some coordination and communication with FSPs. Coordination incurs a small cost but does not require new systems.	No cost	Medium	Requires coordination with IESO and DER assets providers	No cost	Low	Requires some coordination and communication with FSPs. Coordination incurs a small cost but does not require new systems.
2.11	Supply of grid-operational services (Transmission and Distribution) using LDC/DNO assets	New	No cost	Medium	Only applicable for distribution as DNO is not allowed to use assets e.g. battery in a market set up	No cost	N/A	Not applicable, DSO not allowed to own DERs	No cost	N/A	Not applicable, DSO not allowed to own DERs	No cost	N/A	Not applicable, DSO not allowed to own DERs

Table E-4. Market / Mechanism Operation

	Activities	Capability status	Model 1 (regulated DSO)		Notes	Model 2 (dual participation)		Notes	Model 3 (total DSO)		Notes	Model 4 (NMF)		Notes
			DNO Cost	DSO Cost		DNO Cost	DSO Cost		DNO Cost	DSO Cost		DNO Cost	DSO Cost	
3.1	Define and (regularly) revisit services to be procured through distribution markets or the processes to activate flexibility via a regulated congestion mechanism.	New	No cost	Low	Flexibility will be a regulatory requirement. The responsibility would be more on the asset owners and less on the DSO to manage. There would be processes to determine, but not as extensive as in other models in the absence of a flexible market.	No cost	Medium	Limited involvement of systems but requires extensive stakeholder engagement and design of processes with far-reaching consequences. In addition, requires gathering and analysis of benchmarks / case studies to inform design.	No cost	Medium	Limited involvement of systems but requires extensive stakeholder engagement and design of processes with far-reaching consequences. In addition, requires gathering and analysis of benchmarks / case studies to inform design.	No cost	Medium	Limited involvement of systems but requires extensive stakeholder engagement and design of processes with far-reaching consequences. In addition, requires gathering and analysis of benchmarks / case studies to inform design.
3.2	Develop and where possible standardise terms & conditions for flexibility services or rule-based mechanism.	New	No cost	Low		No cost	Medium		No cost	Medium		No cost	Medium	
3.3	Develop and where possible standardise flexibility contractual processes for congestion mechanisms and markets	New	No cost	Low		No cost	Medium		No cost	Medium		No cost	Medium	
3.4	Develop and where possible standardise settlement processes	New	No cost	Low		No cost	Medium		No cost	Medium		No cost	Medium	
3.5	Develop and where possible standardise flexibility trading processes	New	N/A	N/A	Under model 1 there is no flexibility market / trading	No cost	Medium		No cost	Medium		No cost	Medium	
3.6	Develop distribution market rules including for non-discriminatory access to distribution markets and, where required by DER participation model, for facilitation of non-discriminatory access to IAM (for example develop flexibility services stacking rules)	New	N/A	N/A	Under model 1 there is no flexibility market / trading	No cost	Medium	Does not require any systems but does require design of complex processes with high levels of stakeholder engagement	No cost	Medium	Does not require any systems but does require design of complex processes with high levels of stakeholder engagement	No cost	Medium	Does not require any systems but does require design of complex processes with high levels of stakeholder engagement
3.7	Providing information to enable third parties to evaluate prospective investments for DER services to the distribution	New	Low	No cost	Requires publishing of data that should already be available to LDC	Low	No cost	Requires publishing of data that should already be available to LDC	No cost	Low	Requires publishing of data that should already be available to the DSO	No cost	Low	Requires publishing of data that should already be available to the DSO
3.8	Market monitoring, compliance, and enforcement of distribution market rules.	New	N/A	N/A	Under model 1 there is no flexibility market / trading	No cost	Low	Requires some interaction with a 3rd party to share information and interpretation of rules	No cost	Low	Requires some interaction with a 3rd party to share information and interpretation of rules	No cost	Low	Requires some interaction with a 3rd party to share information and interpretation of rules

#	Activities	Capability status	Model 1 (regulated DSO) DNO Cost	Model 1 (regulated DSO) DSO Cost	Notes	Model 2 (dual participation) DNO Cost	Model 2 (dual participation) DSO Cost	Notes	Model 3 (total DSO) DNO Cost	Model 3 (total DSO) DSO Cost	Notes	Model 4 (NMF) DNO Cost	Model 4 (NMF) DSO Cost	Notes
4.1	Developing updated cyber security requirements for DER providing services to the distribution system.	Enhanced	No cost	Low	No system costs. Requires additional cyber security expertise.	No cost	Low	No system costs. Requires additional cyber security expertise.	No cost	Low	No system costs. Requires additional cyber security expertise.	No cost	Low	No system costs. Requires additional cyber security expertise.
4.2	Aggregating DSO-activated DER for participation in IAM (i.e. at floor prices for DSO-activated capacity).	New	N/A	N/A	Under model 1 there is no flexibility market / trading	No cost	Low	DSO must have processes for coordinating with IAM and FSPs. FSP is responsible for aggregating DERs for participation in IAM.	No cost	High	Commercial Aggregator - DSO must have integrated systems for activating and responding to DER participation and aggregating these DERs for IAM	No cost	Medium	Non-commercial Aggregator - DSO must have integrated systems for activating and responding to DER participation and forwarding DER offers to IESO for IAM
4.3	Aggregating non-DSO-activated DER for participation in IAM (i.e. as pass-through to IAM).	New	N/A	N/A	Under model 1 there is no flexibility market / trading	No cost	No cost	No cost, already accounted for in 4.2	No cost	No cost	No cost, already accounted for in 4.2	No cost	No cost	No cost, already accounted for in 4.2
4.4	Translating network congestion into flexibility requirements	New	Low	No cost	DNO uses existing processes to identify congestion but must learn how to translate to flexibility needs	Low	No cost	DNO uses existing systems (accounted in DPND) to identify congestion but must learn how to translate to flexibility needs	No cost	Low	DNO uses existing systems (accounted in DPND). DSO will use DNO-published data to understand flexibility requirements	No cost	Low	DNO uses existing systems (accounted in DPND). DSO will use DNO-published data to understand flexibility requirements
4.5	Impartially operating a local market for distribution services (excludes market for transaction of energy).	New	N/A	N/A	Under model 1 there is no flexibility market / trading	No cost	Medium	DNO uses existing systems (accounted for in DPND). However, data analysis, new processes and new skills are required	No cost	Medium	Systems accounted for in DPND, however data analysis, new processes and new skills are required	No cost	Medium	Systems accounted for in DPND, however data analysis, new processes and new skills are required
4.6	Decision-making on which assets should be activated	New	No cost	Low	Uses the same people but they need to learn new skills and processes. Uses systems that are already in place	No cost	Medium	Uses the data and systems already established for operating the market, requires dedicated people and a higher volume than in model 1 due to the market set up	No cost	Medium	Uses the data and systems already established for operating the market, requires dedicated people and a higher volume than in model 1 due to the market set up	No cost	Medium	Uses the data and systems already established for operating the market, requires dedicated people and a higher volume than in model 1 due to the market set up
4.7	Control the flexible assets	New	No cost	Low	Systems accounted for in several other activities, requires business processes and training to current team	No cost	N/A	DSO is not expected to carry this activity as it FSP's responsibility)	No cost	N/A	DSO is not expected to carry this activity as it FSP's responsibility)	No cost	N/A	DSO is not expected to carry this activity as it FSP's responsibility)
4.8	Operation and maintenance of distribution flexibility trading platforms	New	N/A	N/A	Under model 1 there is no flexibility market / trading	No cost	Low	This requires IT support and engineers to operate the system and maintain it. Under model 2, the IT function could be a shared service with the DNO	No cost	Low	This requires IT support and engineers to operate the system and maintain it.	No cost	Low	Costs could be shared with IESO , making it lower cost. But coordination requirements could increase costs, balancing each other out.
4.9	Manage and schedule DER activation/ flexibility dispatch or curtailment signals in accordance with operating agreements, contracted services, or based on market signals.	New	No cost	Low	Same people as in other activities for the DSO but they require training	Low	No cost	Same people as in other activities for the DNO but they require training	No cost	Medium	Requires a new team	No cost	Low	DNO team could move across to DSO
4.10	Reviewing activation of DER to ensure such operation does not result in adverse distribution system impacts	New	No cost	Low	Requires the same team as in 4.9 with minimal new system requirements	Low	No cost	Requires the same team as in 4.9 with minimal new system requirements	No cost	Low	Requires the same team as in 4.9 with minimal new system requirements	No cost	Low	Requires the same team as in 4.9 with minimal new system requirements
4.11	For cases where DER activated for distribution services, handling all metering, billing and settlement.	New	No cost	Low	Would be performed by the Standard Service Supplier team	Low	No cost	Would be performed by the Standard Service Supplier team	No cost	Medium	Would require a new team to do settlements for the DSO	No cost	Low	Would require a team to do settlements for the DSO. Team could be Standard Service Supplier team moved from DNO.
4.12	For cases where DER aggregated by the DSO for participation in IAM, handling all metering, billing, and settlement.	New	N/A	N/A	Under model 1 there is no flexibility market / trading, assuming it is part of the existing settlement process	N/A	N/A	Under model 2, a 3rd party would manage these processes	No cost	Medium	Requires a new API and training for the same team as 4.11, but no new systems.	No cost	Low	DSO helps to coordinate dispatch of services but is not involved in settlement. May have limited role in providing information / clarifications.
4.13	Assess and record flexibility providers' performance	New	N/A	N/A	Under model 1 there is no flexibility market / trading	Medium	No cost	Requires set up of a new dashboard to analyse data from the market platforms and ADMS performed by DNO	No cost	Medium	Requires set up of a new dashboard to analyse data from the market platforms and ADMS performed by DNO	No cost	Medium	Requires set up of a new dashboard to analyse data from the market platforms and ADMS performed by DNO
4.14	Lead co-ordination on managing and dispatching flexibility with the IESO (and other parties)	New	Low	No cost	IESO coordinates flexibility through bilateral agreements but there is some coordination required	Low	No cost	IESO coordinates flexibility through regulatory mechanisms as well as markets but there is some coordination required	No cost	Low	IESO coordinates flexibility through regulatory mechanisms as well as markets but there is some coordination required	No cost	Low	IESO coordinates flexibility through regulatory mechanisms as well as markets but there is some coordination required

Table E-5. Connection Provision

	Activities	Capability status	Model 1 (regulated DSO) DNO Cost	Model 1 (regulated DSO) DSO Cost	Notes	Model 2 (dual participation) DNO Cost	Model 2 (dual participation) DSO Cost	Notes	Model 3 (total DSO) DNO Cost	Model 3 (total DSO) DSO Cost	Notes	Model 4 (NMF) DNO Cost	Model 4 (NMF) DSO Cost	Notes
5.1	Provide fair and cost-effective distribution network access	Existing	Low	No cost	DNO processes remain largely unaltered, but they must be prepared for a larger volume of connection requests.	Low	No cost	DNO processes remain largely unaltered, but they must be prepared for a larger volume of connection requests.	No cost	High	Requires new processes, a customer management system and a new team	No cost	Low	Processes, systems, teams will transfer across from the DNO
5.2	Provide a range of connection options that meet customer requirements and system needs efficiently	Enhanced	Low	No cost		Low	No cost		No cost	Low	Already accounted for in 5.1	No cost	Low	Already accounted for in 5.1
5.3	Providing data to potential DER applicants to inform DER development, including related to system needs, forecasted curtailments, and historical curtailments	Enhanced	Low	No cost	Low cost as most of the information required here is made available through previous functions	Low	No cost	Low cost as most of the information required here is made available through previous functions	No cost	Low	Low cost as most of the information required here is made available through previous functions	No cost	Low	Low cost as most of the information required here is made available through previous functions
5.4	Studying, approving, and setting operating requirements for new DER connections	Enhanced	Low	No cost	These capabilities are mostly covered in activities 5.1 and 5.2 as well as DN&PD function	Low	No cost	These capabilities are mostly covered in activities 5.1 and 5.2 as well as DN&PD function	No cost	Low	These capabilities are mostly covered in activities 5.1 and 5.2 as well as DN&PD function	No cost	Low	These capabilities are mostly covered in activities 5.1 and 5.2 as well as DN&PD function
5.5	Facilitate queue management of DER connections	New	Low	No cost	Already accounted for in 5.1 and 5.2	Low	No cost	Already accounted for in 5.1 and 5.2	No cost	Low	Already accounted for in 5.1 and 5.2	No cost	Low	Already accounted for in 5.1 and 5.2
5.6	Own DERs	New	No cost	High	Includes capex cost of batteries, local SCADA and communication with ADMS/DERMS	NA	NA		NA	NA		NA	NA	

APPENDIX F. ASSESSMENT BENEFITS

The following assumptions are used to develop the benefits assessment for the different models.

1. The current LDC business model continues in the short term, i.e., utilities primarily earn their return through capital investments. LDCs create value to shareholders by increasing capital investments, i.e., expanding the rate-base through traditional investments.
2. Rules-based or a stricter regulatory structure limits flexibility in commercial decision-making, for instance, to capitalize on opportunities for arbitrage, and can lead to comparatively high transaction costs for delivering services to customers.
3. Decisions that are counter to maximizing value in the current LDC business model (i.e., avoiding capital investments in a model that rewards capital investment) are considered a conflict of interest (perceived or actual).
4. A lower level of perceived conflict of interest can be achieved through a wider separation of business functions.
5. DSOs are designed to optimise the deployment of DERs to maximize network utilization and reduce network costs.
6. A DSO that serves multiple LDCs will have more opportunities to optimise DER flexibility, ceteris paribus.
7. Coordination costs include information sharing, development of working relationships, and development of procedures and policies to define roles and responsibilities.
8. Wider business separation increases coordination costs, i.e., information asymmetry is expected to be lowest in a model where coordination is internalized to a single entity.
9. Coordination/transaction costs are higher when planning across different systems is carried out by different entities (for example, transmission and distribution). Coordination costs are lower when relationships are existing and ongoing

Table F-1. Assessment benefits

Benefits	Description
Avoided Energy Benefit	The estimated benefit of NWS adoption due to avoided energy costs
Avoided Generation Capacity Benefit	The estimated benefit of NWS adoption due to avoided generation capacity needs.
Distribution Capacity (Deferral or Avoidance Benefit)	Accounts for the benefits associated with the deferral or avoidance of the need for traditional infrastructure deployment resulting from the adoption of the NWS

Benefits	Description
Transmission Capacity (Deferral or Avoidance Benefit)	The estimated benefit of NWS adoption due to reductions of peak demand imposed on upstream transmission assets.
Reliability (Net Avoided Interruption Costs)	Accounts for customer interruption costs due to a reduction in frequency and duration of interruptions, primarily associated with the value of lost load
Resilience (Critical Load Benefits)	Accounts for value of serving critical loads during prolonged system interruptions
Innovation & Market Transformation	Accounts for potential future benefits resulting from broader program or market development that is supported by the proposed investment.
Planning Value	Accounts for the option value to support electricity distributor planning

Table F-1. Avoided Energy Costs

Design Features	Model 1 (regulated DSO)	Notes	Model 2 (dual participation)	Notes	Model 3 (total DSO)	Notes	Model 4 (NMF)	Notes
Business Separation*	Low	No separation; cost recovery for system investments are typically tied to energy sales; therefore, activities that reduce energy impacts cost recovery and could introduce regulatory risk in future recovery.	Medium	Some separation; measures to reduce perceived conflicts with the current business model allows the DSO to avoid energy by optimizing DERs. The benefit is increased if the optimization is accrued across multiple LDCs	High	Highest degree of business and functional separation reduces barriers to avoid energy costs on the system by optimizing DERs on the systems	Medium	Some separation; measures to reduce perceived conflicts with the current business model allows the DSO to deliver avoided energy benefit across multiple LDCs
Functional Separation*	N/A		Medium	**Wider** degree of functional separation supports the potential to avoid energy costs across multiple LDCs; measures to reduce perceived conflicts required for optimizing DERs	Highest		High	**Widest** degree of functional separation increases the potential to avoid energy costs on the system; measures to reduce perceived conflicts required for optimizing DERs
Hierarchy	Low	Serves a single LDC which increases the risk of creating a fragmented market with limited liquidity for energy products and services	Medium	The potential to operate in multiple LDCs increases opportunities to avoid energy costs; effectiveness impacted by internal organizations and information asymmetry with external LDC	High	The potential to operate in multiple LDCs increases opportunities to avoid energy costs; DSO is independent of the LDCs served but relies on LDCs for all distribution information which increases information asymmetry;	Medium	The potential to operate in multiple LDCs increases opportunities to avoid energy across multiple LDCs; operational effectiveness impacted organization structure and information asymmetry with external LDC
Ownership of Flexible Resources	Low	Some ownership and associated costs; limited to one LDC and optimizing DERs to avoided energy (kWh) counter to volumetric cost recovery	Medium	No ownership costs and DSO can optimize DERs across multiple LDCs to execute mechanisms that avoid energy at higher costs; cost recovery for system investments are typically tied to energy sales which may impact potential delivery of benefits.	High	No ownership costs and DSO can optimize DERs across multiple LDCs to capitalize on opportunities to avoid energy at higher costs	Medium	No ownership costs and DSO can optimize DERs across multiple LDCs to execute mechanisms that avoid energy at higher costs; cost recovery for system investments are typically tied to energy sales which may impact potential delivery of benefits.
Flexibility Mechanisms	Low	Regulatory structure limits operational flexibility to optimize across markets or products; avoided energy (kWh) counter to traditional business model with volumetric rates	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for deployment of resources to avoided energy across multiple LDCs	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for deployment of resources to avoided energy across multiple LDCs	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for deployment of resources to avoided energy across multiple LDCs
Flexibility market procurement and dispatch	N/A		High	Separation between the DSO and the aggregators could allow for increased perception of transparency in the market; transmission and distribution coordinated and co-optimized.	Highest	DSO plays the role of the aggregator (not the 3rd party) which increases flexibility to avoid energy costs	Medium	Additional coordination needed between the DSO and IESO to optimize local network and forward bids. Prioritization of the local network could enhance distribution activities but may lead to suboptimal DER utilization/value at the transmission level
System coordination and operation	Low	Coordination would be internalized but avoided energy (kWh) is not supported by traditional business model with volumetric rates	High	DSO can coordinate and optimize DERs across multiple LDCs to provide avoided energy benefits; organizational structure increases perception of conflict of interest.	Highest	Reduces barriers to avoid energy on the system by optimizing DERs across multiple LDCs	Medium	The shared market platform allows for greater optimization of solutions (DER or traditional) across the distribution network; Prioritization of local network could impact timing/value of resources forwarded to the IESO; organizational structure increases perception of conflict of interest.
Network design & development	Low	Design and development limited by the size of the DSO service area and avoided energy (kWh) may limit need for capital investment which counter traditional regulated rate of return models	Medium	Shared responsibility between the DSO and the LDC for long-term planning can affect the adoption of mechanisms that avoided energy use by LDC customers and potentially impact near-term cost-recovery.	Highest	DSO would be fully responsible for the long-term planning of the network and for outage planning	High	DSO would be fully responsible for the long-term planning of the network and for outage planning. Prioritization of local network could enhance delivery of benefits on the distribution system but may lead to suboptimal outcomes on the transmission system.

Table F-2. Avoided Generation Capacity Costs

Design Features	Model 1 (regulated DSO)	Notes	Model 2 (dual participation)	Notes	Model 3 (total DSO)	Notes	Model 4 (NMF)	Notes
Business Separation	Low	No separation; opportunities to avoid generation capacity may be lower in a single LDC model	Medium	Some separation; measures to reduce perceived conflicts within the organization. Potential to delivery avoided generation capacity costs increased when DERs optimized across multiple LDCs.	High	Highest opportunity to avoid generation capacity costs due to playing a greater role in transmission and distribution operation	Medium	Some separation; measures to reduce perceived conflicts within the organization. Potential to delivery avoided generation capacity costs increased when DERs optimized across multiple LDCs.
Functional Separation	N/A		Medium	Wider degree of functional separation supports the potential to avoid generation capacity costs; measures to reduce perceived conflicts required for optimizing DERs	Highest		High	Widest degree of functional separation increases the potential to avoid generation capacity costs; measures to reduce perceived conflicts required for optimizing DERs
Hierarchy	Low	Serving a single LDC limits the size of the market and the amount of DER capacity that can be procured in the service area to meet capacity needs	Medium	The potential to operate in multiple LDCs increases opportunities to avoid generation capacity costs; effectiveness of the model impacted by internal organizations structure and information asymmetry with external LDC	High	The potential to operate in multiple LDCs increases opportunities to avoid generation cost due to transmission and distribution role of the DSO.	Medium	The potential to operate in multiple LDCs increases opportunities to avoid generation costs; DSO plays increased role in managing the local network needs and coordination with IESO; Information asymmetry with external LDC
Ownership of Flexible Resources	Low	Some ownership and associated costs; Size of the market and regulations limit the procurement of resources to meet capacity needs	Medium	No ownership costs and DSO can optimize DERs across multiple LDCs to manage and avoid generation capacity costs	Medium	No ownership costs and DSO can optimize DERs across multiple LDCs to manage and avoid generation capacity costs	Medium	No ownership costs and DSO can optimize DERs across multiple LDCs to manage and avoid generation capacity costs
Flexibility Mechanisms	Low	Regulatory structure limits operational flexibility to procure and deploy resources to meet capacity needs	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for utilizing resources to avoid generation capacity costs across multiple LDCs	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for utilizing resources to avoid generation capacity costs across multiple LDCs	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for utilizing resources to avoid generation capacity costs across multiple LDCs
Flexibility market procurement and dispatch	N/A		High	Coordination required with 3rd parties to procure DERs to meet generation capacity needs; transmission and distribution coordinated and co-optimized.	High	DSO plays the role of the aggregator (not the 3rd party) which increases flexibility to avoid generation capacity costs	Medium	Coordination required with 3rd parties to procure DERs to meet generation capacity needs. Prioritization of the local network could enhance distribution activities but may lead to suboptimal DER utilization/value at the transmission level
System coordination and operation	Low	Coordination would be internalized but total value of avoided generation capacity is less due to serving a single LDC and limited opportunities to procure or provide capacity in the model	High	DSO can coordinate and optimize DERs across multiple LDCs to procure, manage, and avoid generation capacity	Highest	DSO structure has more operational flexibility to optimize DER deployment for multiple products or LDCs to procure, manage, and avoid generation capacity	Medium	The shared market platform allows for greater optimization of solutions (DER or traditional) across the distribution network; Prioritization of local network could impact timing/value of resources forwarded to the IESO; organizational structure increase perception of conflict of interest.
Network design & development	Low	Design and development limited by the size of the DSO service area which limits the total value of potential avoided generation capacity benefits	Medium	Shared responsibility between the DSO and the LDC for long-term planning which can affect the adoption of mechanisms that avoid generation capacity for LDC customers	Highest	DSO would be fully responsible for the long-term planning of the network and for outage planning which increase opportunities to avoid generation capacity costs	High	DSO would be fully responsible for the long-term planning of the network and for outage planning. Prioritization of local network could enhance delivery of benefits on the distribution system but may lead to suboptimal outcomes on the transmission system.

Table F-3. Distribution Capacity (Deferral or Avoidance Benefit)

Design Features	Model 1 (regulated DSO)	Notes	Model 2 (dual participation)	Notes	Model 3 (total DSO)	Notes	Model 4 (NMF)	Notes
Business Separation	Low	No separation; distribution investment deferral is counter to current business model that provides a regulated rate of return for capital investments	Medium	Some separation; measures to reduce perceived conflicts based on the organizational structure.	Medium	Incentivized to deliver avoided distribution capacity benefit on the system by maximizing deferral investment and optimizing DERs but information acquisition costs may be higher due to relying on LDC for distribution information	Medium	Some separation; measures to reduce perceived conflicts with the current business model allows the DSO to avoid energy by optimizing DERs. The benefit is increased if the optimization is accrued across multiple LDCs
Functional Separation	N/A		Medium	Wider degree of functional separation supports the potential to deferral capacity costs; measures to reduce perceived conflicts required for optimizing DERs	High		Highest	Widest degree of functional separation increases the potential to avoid distribution capacity costs on the system; Prioritization of the local network could enhance ability to optimize DERs to avoid distribution capacity costs
Hierarchy	Low	Serves a single LDC creates a fragmented market with limited liquidity to provide services on the distribution system	Medium	The potential to operate in multiple LDCs increases opportunities to manage distribution capacity across multiple LDCs to defer distribution investments; effectiveness impacted by internal organizations and information asymmetry with external LDC	High	The potential to operate in multiple LDCs increases opportunities to optimize distribution capacity benefits; DSO relies on LDCs for all distribution information which increases information asymmetry	Medium	The potential to operate in multiple LDCs increases opportunities to manage distribution capacity across multiple LDCs to defer distribution investments; effectiveness impacted by internal organizations and information asymmetry with external LDC
Ownership of Flexible Resources	Low	Some ownership and associated costs; optimizing DERs to avoided distribution investment is counter to traditional regulated rate of return models	Medium	No ownership costs and DSO can optimize resources across multiple LDCs to avoid distribution capacity investments, but deferral benefits may negate opportunities to earn a regulated rate of return.	High	No ownership costs and DSO can optimize resources across multiple LDCs to avoid distribution capacity investments; Lowest potential of conflict interest in avoiding distribution investment.	Medium	No ownership costs and DSO can optimize resources across multiple LDCs to avoid distribution capacity investments, but deferral benefits may negate opportunities to earn a regulated rate of return.
Flexibility Mechanisms	Low	Regulatory structure limits operational flexibility to optimize across markets or products; avoided distribution investment is counter to traditional regulated rate of return models	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for utilizing resources to avoid distribution capacity investments across multiple LDCs	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for utilizing resources to avoid distribution capacity investments across multiple LDCs	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for deployment of resources to avoided energy across multiple LDCs
Flexibility market procurement and dispatch	N/A		Medium	Coordination required with 3rd parties to procure DERs impacts ability to avoid distribution capacity costs relative to Model 3	High	DSO plays the role of the aggregator (not the 3rd party) with increased flexibility;	Highest	Coordination required with 3rd parties to procure DERs impacts ability to avoid distribution capacity costs . Prioritization of the local network could enhance ability to optimize DERs to avoid distribution capacity costs
System coordination and operation	Low	Coordination would be internalized but avoided distribution investment is not supported by traditional business model with volumetric rates	Medium	DSO can coordinate and optimize DERs across multiple LDCs to provide avoided energy benefits; organizational structure increase perception of conflict of interest.	Medium	DSO and IESO coordination required to deliver potential avoid distribution capacity benefits on the system by optimizing DERs across multiple LDCs; Distribution and transmission considered equally.	Highest	The shared market platform allows for greater optimization of solutions (DER or traditional) across the distribution network; Prioritization of local network could impact timing/value of resources forwarded to the IESO; organizational structure increase perception of conflict of interest.
Network design & development	Low	Design and development limited by the size of the DSO service area and avoiding capital investment is not supported by traditional regulated rate of return models	Medium	Shared responsibility between the DSO and the LDC for long-term planning which can affect the adoption of mechanisms that avoided distribution investments by LDC customers	High	DSO would be fully responsible for the long-term network and outage planning which increases opportunities to defer distribution investment	Highest	DSO would be fully responsible for the long-term planning of the network and for outage planning. Prioritization of local network could enhance delivery of benefits on the distribution system.

Table F-4. Transmission Capacity (Deferral or Avoidance Benefit)

Design Features	Model 1 (regulated DSO)	Notes	Model 2 (dual participation)	Notes	Model 3 (total DSO)	Notes	Model 4 (NMF)	Notes
Business Separation	Low	No separation (T&D); transmission capacity investment deferral is not supported in a model with regulated rate of return for capital investments	Medium	Some separation; measures needed to reduce perceived conflicts based on the organizational structure.	High	DSO takes greater responsibility and has capability to provide services to transmission network; Highest incentives to deliver avoided transmission capacity benefit on the system by maximizing by DERs; potentially higher information acquisition costs due to separation	Medium	Some separation; measures needed to reduce perceived conflicts based on the organizational structure.
Functional Separation	N/A		Medium	Wider degree of functional separation supports the potential to defer transmission capacity costs; measures needed to reduce perceived conflicts required for optimizing DERs	Highest		High	Operation across multiple LDCs, required coordination with IESO, and widest degree of functional separation increases the potential to avoided transmission capacity costs on the system; potential delivery of benefits is a function of how measures are implemented to reduce perceived conflicts
Hierarchy	Low	Serves a single LDC creates a fragmented market with limited liquidity to provide services on the transmission system	Medium	DSO operates in multiple LDCs which increases opportunities to manage transmission capacity across multiple LDCs; effectiveness impacted by internal organizations and information asymmetry with external LDC	High	DSO plays a greater role in transmission operation but potentially faces higher cost to incorporate distribution system information into the transmission planning process	Medium	DSO operates in multiple LDCs which increases opportunities to manage transmission capacity across multiple LDCs; effectiveness impacted by internal organizations and information asymmetry with external LDC
Ownership of Flexible Resources	Low	Some ownership and associated costs; business activities that avoided transmission investment is not supported by traditional regulated rate of return models	Medium	No ownership costs and DSO can optimize resources across multiple LDCs to avoid transmission capacity investments; DSO relies on IESO to handle transmission operation	High	No ownership costs; DSO takes greater responsibility and has capability to provide services to transmission network;	Medium	No ownership costs and DSO can optimize resources across multiple LDCs to avoid transmission capacity investments; DSO relies on IESO address transmission operation but plays a larger role in coordinating DERs
Flexibility Mechanisms	Low	Regulatory structure limits operational flexibility to optimize across markets or products; avoided transmission investment is not supported in traditional regulated rate of return models	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for utilizing resources to avoid transmission capacity investments across multiple LDCs	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for utilizing resources to avoid transmission capacity investments across multiple LDCs	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for deployment of resources to avoided energy across multiple LDCs
Flexibility market procurement and dispatch	N/A		High	Coordination required across multiple entities to manage transmission capacity costs	Highest	DSO takes greater responsibility and has capability to provide services to transmission network	Medium	Coordination required across multiple entities to manage transmission capacity costs; Bidding process and coordination with IESO to manage DER bids increases costs.
System coordination and operation	Low	Coordination would be internalized but avoided distribution investment is not supported by traditional business model with volumetric rates	High	DSO can coordinate and optimize DERs across multiple LDCs to facilitate avoided transmission capacity benefits	Highest	Coordination with IESO required but DSO takes greater responsibility and has capability to provide services to transmission network	Medium	DSO can coordinate and optimize DERs across multiple LDCs to provide avoided transmission capacity benefits. DSO role in the bidding process could impact the transmission optimization.
Network design & development	Low	Design and development limited by the size of the DSO service area and avoiding capital investment is not supported by traditional regulated rate of return models	Medium	Shared responsibility between the DSO and the LDC for long-term planning which increases coordination costs and potential delivery of benefits.	Highest	DSO would be fully responsible for the long-term network and outage planning which increases opportunities to defer transmission investment	High	DSO would be fully responsible for the long-term planning of the network and for outage planning. Coordination with IESO creates greater opportunities to improve network design and development related to transmission capacity.

Table F-5. Reliability (Net Avoided Interruption Costs)

Design Features	Model 1 (regulated DSO)	Notes	Model 2 (dual participation)	Notes	Model 3 (total DSO)	Notes	Model 4 (NMF)	Notes
Business Separation	Low	No separation; LDC is familiar with system needs and conditions, but the value of reliability benefits limited to a single LDC	Medium	Some separation; DSO has familiarity with reliability procedures and standards which allows them to deliver potentially the highest reliability benefits across the LDCs	Medium	Independence from the LDCs creates higher information asymmetry; the independent DSO is least familiar with reliability existing system conditions and needs across the LDCs	Medium	Some separation; DSO has familiarity with reliability procedures and standards which allows them to deliver potentially the highest reliability benefits across the LDCs
Functional Separation	N/A		High	Potential delivery of reliability benefits are enhanced by the DSO's familiarity with reliability procedures and standards but may be limited by the wider degree of functional separation and measures to reduce perceived conflicts	Medium		Highest	Potential delivery of reliability benefits are enhanced by the DSO's familiarity with reliability procedures and standards but may be limited by the widest degree of functional separation and measures to reduce perceived conflicts; Prioritization of the local network increases the DSO's ability to maintain and address reliability issues
Hierarchy	Low	Serving a single LDC limits opportunities to optimize DERs services that could improve reliability and avoid interruptions	Medium	The potential to operate DERs in multiple LDCs increases opportunities to deploy services that improve reliability and avoid system interruptions costs;	Medium	The potential to operate DERs in multiple LDCs increases opportunities to deploy services that improve reliability and avoid system interruptions costs;	Medium	The potential to operate DERs in multiple LDCs increases opportunities to deploy services that improve reliability and avoid system interruptions costs;
Ownership of Flexible Resources	Low	Some ownership and associated costs; ownership of DERs could improve effective deployment to support reliability in the LDC but deployment limited to rules-based mechanisms	Medium	No ownership costs and DSO can optimize DERs across multiple LDCs to execute mechanisms to improve reliability and avoid interruptions	Medium	No ownership costs and DSO can optimize DERs across multiple LDCs to execute mechanisms to improve reliability and avoid interruptions	Medium	No ownership costs and DSO can optimize DERs across multiple LDCs to manage reliability
Flexibility Mechanisms	Low	Regulatory structure limits the value of avoided interruptions to a single LDC and limits operational flexibility to optimize reliability across markets or products	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for utilizing resources to maximize net avoided interruption costs	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for utilizing resources to maximize net avoided interruption costs	Medium	Market-based regulation increases types of mechanisms that can be deployed to maintain reliability across multiple LDCs
Flexibility market procurement and dispatch	N/A		High	DSO is responsible for procuring DERs from 3rd parties to manage congestion and reliability on the energy systems; Delivery of potential benefits increase with transmission reliability being co-optimized.	Highest	DSO provides congestion services hence plays a role of the aggregator (not the 3rd party); Potential benefits increases with role in the transmission and distribution operations.	Medium	Prioritization of the local network increases the DSO's ability to maintain and address reliability issues; DER utilization and valuation may more closely align with prioritization protocols during scarcity or emergencies.
System coordination and operation	Low	Coordination would be internalized to the LDC potentially limiting the total value of avoided interruptions	High	DSO can coordinate and optimize DERs across multiple LDCs to manage reliability; organizational structure increase perception of conflict of interest.	Highest	DSO structure has more operational flexibility to optimize DER deployment for multiple products or LDCs manage reliability; Potential benefits increases with role in the transmission and distribution operations.	Medium	The shared market platform allows for greater optimization of solutions (DER or traditional) across the distribution network; Additional system coordination and planning needed based on the DSO's role in the bidding process; organizational structure increase perception of conflict of interest.
Network design & development	Low	Design and development limited by the size of the DSO service area which limits the total value of potential reliability benefits	Medium	Shared responsibility between the DSO and the LDC to ensure reliability. DSO has familiarity with reliability procedures and standards which allows them to deliver potentially the highest reliability benefits across the LDCs.	Highest	DSO would be fully responsible for the long-term planning of the network and for outage planning. Increased coordination need between the DSO and LDCs to manage interruption costs.	High	DSO would be fully responsible for the long-term planning of the network and for outage planning. Prioritization of local network could enhance options to maintain reliability at the distribution level.

Table F-6. Resilience (Critical Load Benefits)

Design Features	Model 1 (regulated DSO)	Notes	Model 2 (dual participation)	Notes	Model 3 (total DSO)	Notes	Model 4 (NMF)	Notes
Business Separation	Low	No separation; LDC is familiar with system and customer needs but the value of resilience benefits in a single LDC may be relatively low	Medium	Some separation; DSO has familiarity with system and customer needs; potential to deliver the highest resilience benefits across the LDCs	Medium	DSO is less familiar with system and customer needs across the LDCs: independence from the LDCs creates higher information asymmetry.	Medium	Some separation; DSO has familiarity with system and customer needs; potential to deliver the highest resilience benefits across the LDCs
Functional Separation	N/A		Medium	Wider degree of functional separation increases opportunities to coordinate to across the organization to plan for resilience.	High		Highest	Widest degree of functional separation limits ability to coordinate to across the organization to plan for resilience but familiarity with system and customer needs support higher potential benefit deliver.
Hierarchy	Low	Serving a single LDC limits opportunities to optimize DERs services that could improve resilience and serve critical loads	Medium	The potential to operate in multiple LDCs increases opportunities to deploy services that improve resilience and serve critical load customers; More familiarity with customer needs	Medium	The potential to operate in multiple LDCs increases opportunities to deploy services that improve reliability and avoid system interruptions costs	Medium	Prioritization of local network enhances the DSO's ability to address resilience
Ownership of Flexible Resources	Low	Some ownership and associated costs; ownership of DERs could improve resilience but value limited to a single LDC service area; Rules-based mechanisms limits flexibility to increase the value of resilience	Medium	No ownership costs and DSO can optimize DERs across multiple LDCs to execute mechanisms to improve resilience and service critical load customers	Medium	No ownership costs and DSO can optimize DERs across multiple LDCs to execute mechanisms to improve resilience and service critical load customers	Medium	No ownership costs and DSO can optimize DERs across multiple LDCs to execute mechanisms to improve resilience and service critical load customers
Flexibility Mechanisms	Low	Potential value of resilience is potentially less in single LDC; deployment is limited to rules-based mechanisms; regulatory structure limits operational flexibility to optimize resources across markets or products	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for utilizing resources to maximize the value of resilience	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for utilizing resources to maximize the value of resilience	Medium	Market-based regulation increases types of mechanisms that can be deployed to address resilience across multiple LDCs
Flexibility market procurement and dispatch	N/A		High	DSO is responsible for procuring DERs from 3rd parties to deliver resilience benefits on the energy systems.	Highest	DSO has greater responsibility and provides services capable of delivering resilience on the systems	Medium	DSO is responsible for procuring DERs from 3rd parties to deliver resilience benefits on the energy systems. Prioritization of the local network enhances the DSO's ability to adopt measures to support distribution resilience.
System coordination and operation	Low	Coordination would be internalized to the LDC potentially limiting the total value of avoided interruptions	High	DSO can coordinate and optimize DERs across multiple LDCs to manage resilience; organizational structure increase perception of conflict of interest.	Highest	DSO structure has more operational flexibility to optimize DER deployment for multiple products or LDCs manage resilience	Medium	The shared market platform allows for greater optimization of solutions (DER or traditional) across the distribution network; Additional system coordination and planning needed based on the DSO's role in the bidding process; organizational structure increase perception of conflict of interest.
Network design & development	Low	Design and development limited by the size of the DSO service area which limits the total value of potential resilience benefits	Medium	Shared responsibility between the DSO and the LDC for long-term planning to provide resilience on the energy systems	Highest	DSO would be fully responsible for the long-term planning of the network and for outage planning.	High	DSO would be fully responsible for the long-term planning of the network and for outage planning. Prioritization of local network could enhance options to support resilience on the distribution system.

Table F-7. Innovation & Market Transformation

Design Features	Model 1 (regulated DSO)	Notes	Model 2 (dual participation)	Notes	Model 3 (total DSO)	Notes	Model 4 (NMF)	Notes
Business Separation	Low	No separation; rules-based regulations and internalization of procedures and polices may limit innovation	Medium	Some separation; serving a broader stakeholder group could increase innovation and market transformation opportunities	Medium	Business and function separations in the DSO independent model could lead to highest innovation to meet the needs of different stakeholders	Medium	Some separation; serves a broader stakeholder group could increase innovation and market transformation opportunities
Functional Separation	N/A		Medium	Wider separation of functions and serving a broader stakeholder group could supports innovation and market transformation opportunities	High		High	Widest separation of functions and serves a broader stakeholder group could increase innovation and market transformation opportunities
Hierarchy	Low	Internalization of procedures and polices to a single organization and LDC may limit innovation	Medium	Broader stakeholder group across multiple LDCs could supports higher innovation and transformation due to exposure to different market forces	Medium	Broader stakeholder group across multiple LDCs could supports higher innovation and transformation due to exposure to different market forces	Medium	Broader stakeholder group across multiple LDCs could supports higher innovation and transformation due to exposure to different market forces
Ownership of Flexible Resources	Low	Some ownership and associated costs; regulatory structure limits operational flexibility to develop innovative products and pursue market transformation	Medium	No ownership costs and DSO can increase innovation and market transformation by learning from other LDCs to improve products and services offered	Medium	No ownership costs and DSO can increase innovation and market transformation by learning from other LDCs to improve products and services offered	Medium	No ownership costs and DSO can increase innovation and market transformation by learning from other LDCs to improve products and services offered
Flexibility Mechanisms	Low	Regulatory structure limits operational flexibility to deploy innovative products and pursue market transformation	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for deployment of resources to increase innovation and market transformation	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for deployment of resources to increase innovation and market transformation	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies for deployment of resources to increase innovation and market transformation
Flexibility market procurement and dispatch	N/A		Medium	Broader stakeholder group across multiple LDCs could supports innovative approaches to procure and dispatch resources	High	DSO has greater role which an increase flexibility to develop mechanisms to procure and dispatch resources	Medium	The structure of the model increases opportunities for innovation and market transformation on the distribution system but prioritization of local network could impact ability to optimize potential benefits across the energy system.
System coordination and operation	Low	Coordination limited to a single LDC which limits the value relative to other models	High	DSO coordination across multiple LDCs and with different stakeholders supports innovation;	Highest	DSO takes greater responsibility in system coordination; DSO has the highest incentives to pursue market-based approaches to increase value proposition	Medium	The shared market platform and increased coordination between the DSO and IESO creates additional opportunities for innovation and market transformation.
Network design & development	Low	Design and development of innovation on the network limited by the size of the DSO service area	Medium	Shared responsibility between the DSO and the LDC for long-term planning (including innovation and transformation) on the energy systems leads to some reduction in efficiency and resulting benefit relative to a DSO with greater responsibility for planning	Highest	DSO takes greater responsibility for long-term planning to provide which allows for more flexibility to implement innovative solutions on the energy systems	High	DSO takes greater responsibility for long-term planning to provide which allows for more flexibility to implement innovative solutions on the energy systems. Prioritization of local network could limit opportunities to innovate.

Table F-8. Planning Value

Design Features	Model 1 (regulated DSO)	Notes	Model 2 (dual participation)	Notes	Model 3 (total DSO)	Notes	Model 4 (NMF)	Notes
Business Separation	Low	No separation; planning would be internalized but planning value would be limited to a single service territory	High	Some separation; more internalized experience with system planning than Model 3; planning value across multiple LDCs provides increased opportunities for improving processes	Medium	Planning value across multiple LDCs provides increased opportunities for improvement	High	Some separation; more internalized experience with system planning than Model 3; planning value across multiple LDCs provides increased opportunities for improving processes
Functional Separation	N/A		Medium		Medium		Medium	Widest degree of functional separation limits the ability to coordinate to across the organization to plan
Hierarchy	Low	Internalization of procedures and polices to a single organization and LDC may limit planning value relative to other models	Medium	Broader stakeholder group across multiple LDCs provides increased opportunities for learning and improvement	Medium	Broader stakeholder group across multiple LDCs provides increased opportunities for learning and improvement	Medium	Broader stakeholder group across multiple LDCs provides increased opportunities for learning and improvement
Ownership of Flexible Resources	Low	Ownership of resources provide some planning value that can be used for planned outages, etc. but limited opportunities to extract value due to the relative size of the DSO	Medium	No ownership costs and DSO can increase planning value by developing strategies to procure, deploy, and manage resources across multiple LDCs	Medium	No ownership costs and DSO can increase planning value by developing strategies to procure, deploy, and manage resources across multiple LDC	Medium	No ownership costs and DSO can increase planning value by developing strategies to procure, deploy, and manage resources across multiple LDCs.
Flexibility Mechanisms	Low	Rules-based structure limits flexibility mechanisms to optimize DERs in planning	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies to utilize resources to provide value in the planning process.	Medium	Market-based regulation increases Market-based regulation increases types of mechanisms that can be deployed and strategies to utilize resources to provide value in the planning process.	Medium	Market-based regulation increases types of mechanisms that can be deployed and strategies to utilize resources to provide value in the planning process.
Flexibility market procurement and dispatch	N/A		High	Broader stakeholder group across multiple LDCs increase opportunities to learn and develop strategies to optimize procure and dispatch resources	Highest	DSO has greater role in planning which potentially enhances the ability to develop flexibility mechanisms to procure and dispatch resources	Medium	Broader stakeholder group across multiple LDCs increase opportunities to learn and develop strategies to optimize procure and dispatch resources; Prioritization of local network increases opportunities and enhance strategies to procure and dispatch DERs.
System coordination and operation	Low	Coordination would be internalized to the LDC potentially limiting the total planning value	High	DSO and IESO share in system coordination and operation. Operation in multiple LDCs increases opportunities to develop processes that improve planning;	Highest	DSO plays a greater role in system operations which has the potential to improve planning	Medium	Operation in multiple LDCs increases opportunities to develop processes that improve planning; DSO has greater role in coordinating bids and experience with system planning and coordination to create additional value
Network design & development	Low	Planning value related to design and development of the network limited by the size of the DSO service area relative to the other models	Medium	Shared responsibility between the DSO and the LDC for long-term planning value on the energy systems	Highest	DSO takes greater responsibility for long-term planning of the network which increase the planning value in the DSO model	High	Shared responsibility between the DSO and the LDC for long-term planning value on the energy systems; Prioritization of local network enhances planning value at the distribution level.

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